GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

FOR THE YEAR

1894

TRENTON NEW JERSEY
THE JOHN L. MURPHY PUBLISHING COMPANY PRINTERS
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To His Excellency George T. Werts, Governor of the State of New Jersey, and ex-officio President of the Board of Managers of the Geological Survey of New Jersey:

SIR—I beg leave to present herewith the Annual Report of the Geological Survey for 1894.

Respectfully submitted,

JOHN C. SMOCK,
State Geologist.

TRENTON, N. J., January 22d, 1895.

PART I.

SURFACE GEOLOGY.

REPORT OF PROGRESS

BY

ROLLIN D. SALISBURY.

SURFACE GEOLOGY—REPORT OF PROGRESS.

1894.

BY ROLLIN D. SALISBURY.

PREFACE.

During the summer of 1894 I spent about three months in the field. During the season I had the assistance of Messrs. H. B. Kümmel, C. E. Peet and G. N. Knapp. Mr. Peet was in the field about three months, and Messrs. Kümmel and Knapp about five months each. Work was carried on both in the northern and southern parts of the State. The areal work in the glaciated area was completed, and good progress was made in the region farther south, especially in the western part of the State, in Mercer, Burlington and Monmouth counties. A map accompanying this report indicates the extent of territory in which work has been virtually completed so far as the surface geology is concerned.

The area thus far covered has been studied in much detail. Further work of the same sort needs to be done in the southwestern corner of Burlington county and in western Gloucester, Salem and Cumberland counties. It is not now thought that it will be necessary or wise to study the timber-covered area of the southeastern part of the State in similar detail. In the first place, there are so few exposures and available sections that there could be but poor returns from exhaustive study. In the second place, the region is not of such importance, from the economic standpoint, as to warrant great expenditure in the study of its surface geology. In the third place, it is believed that the geological questions involved in this area will be largely settled when the study of its surroundings has been completed. It is true that there are various limited areas within the

timber-covered region which are of much importance, and which will repay careful study; to these attention will be given.

The field work of the season emphasized the importance of the point referred to in my last report concerning the considerable influence of stagnant ice upon the deposition of the stratified drift of the valleys of the northern part of the State. This topic, briefly referred to in my last report, is now presented in greater detail in connection with the stratified drift of the glaciated region.

The work of the season tended to confirm the correctness of the general position already taken concerning the history of the yellow gravel formations. The Pensauken and Jamesburg formations are more fully described, and their relations more fully set forth in this report. The study of these formations has brought to light important information regarding the supply of material for the construction of roads, and further study will do more in the same line. It will be a part of the purpose of further work to make information on this point available. It is evident that many portions of the southern part of the State have an abundant supply of road material of high grade. Some of it is of such a character as to fit it for immediate application. More of it is of such a nature that a considerable degree of intelligence in its handling is necessary, in order to secure the best results. It is probable that a little experimentation upon the best methods of handling and combining various materials would well repay the cost involved.

SECTION I.

DRIFT DEPOSITS OF NEW JERSEY NORTH OF THE MORAINE—OUTLINE SKETCH.

Geography of northwestern New Jersey.—A few words concerning the general geographical relations of this area may well precede the summary of its drift. Near its western border lies the Kittatinny mountain, which consists of an even-crested ridge to the south, and a narrow rolling plateau to the north. Eight or ten miles east of the Kittatinny range is the highland area of the crystalline schists. Between these elevations, and bounded by them on the northwest and southeast respectively, lies the broad depression known as the Kittatinny valley. Roughly speaking, the Kittatinny valley may be said to be about 600 feet lower than the Kittatinny mountain on the west, and about 450 feet lower than the crystalline schist highland on the east.

The even-crested Kittatinny range, and the mountains of the highland region east of the valley are not mountains produced by the folding of the strata of which they are composed. Their structure and their relations make it certain that they are the remnants of a plateau which was once continuous over the Kittatinny valley, from the highlands on the east to the mountain range on the west.

At the beginning of its history, so far as it can now be read, the surface of this plateau was not altogether plane. It had a relief of one, two, or even three hundred feet. Nevertheless it approached planeness.

The structure of the rock underlying this old plateau is such as to demonstrate that its surface was produced by the degradation of a still older and higher surface. This degradation is believed to have been effected by streams, which had so far widened their valleys, and so far obliterated the inter-stream ridges as to have developed the sort of surface referred to above. Such a surface has been called a peneplain. Peneplains of this type are developed only at low altitudes.

In the development of this peneplain, the softer rocks were worn down more readily than the harder, and the latter occasioned the

swells which stood above the general level, giving rise to the relief of the surface, and constituted the whole a peneplain, as distinct from a base-level plain. High Point was one of these unsubdued remnants of the earlier and higher land surface. This peneplain of northwestern New Jersey has been named by Davis the Schooley peneplain,* from the remnant of it which still remains as Schooley mountain.

The elevation of this peneplain transformed it into a plateau. During the slow transformation of the peneplain into the plateau, the gradient of its streams was increased, and with increased energy they set to work to carve out valleys in the surface of the plateau. The softer formations—the limestone and the shale—yielded to the agencies of surface degradation much more readily than the crystalline schists or than the hard conglomerates of the Kittatinny mountain. The result was that surface drainage lowered the surface of the limestone and shale much more rapidly than it lowered the adjacent surfaces of crystalline schist and Oneida conglomerate. Along the belt where the former come to the surface, there was developed a broad plain several hundred feet below the level of the plateau on either hand. This broad plain is the Kittatinny valley, where no trace of the Schooley peneplain remains. On the harder rocks on either side of this broad valley, erosion made so much less rapid headway that the Schooley peneplain level is still represented along the even crests of the mountains, and on the level-topped inter-stream areas at high elevations.

After the broad Kittatinny valley plain had been developed, the region suffered further uplift. This uplift gave the streams greater fall, and so increased their vigor. In the surface of the Kittatinny valley plain thus elevated, they carved new and deeper valleys, through which the streams of that region now flow.

The Green Pond mountain range is in all ways comparable to the Kittatinny mountain in its general relations and in its geographic history. Like the latter, it is an erosion remnant of the Schooley peneplain. Because it resisted erosion more effectively than the formations immediately adjacent to it on the east and west, it is believed to have stood somewhat above its surroundings when the peneplain was at its best.

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* Davis, "The Geographic Development of Northern New Jersey." Proc. Boston Society of Nat. Hist., Vol. XXIV., page 365.

Either the Schooley peneplain was not flat, or subsequent uplifts have not affected all parts of it equally. This is shown by the fact that the crest of the Kittatinny mountain has an elevation 100 to 200 feet greater than that of the highland area to the east, while the eastern part of the highlands is not so high as the western.

Three cycles of erosion with intervening uplifts are thus clearly indicated in the northwestern part of the State. The first cycle developed the Schooley peneplain, of which the Kittatinny mountain and the higher parts of the highland east of the Kittatinny valley are remnants. The second cycle followed the uplift of the Schooley peneplain, and developed the broad Kittatinny valley several hundred feet lower than the surface of the uplifted peneplain. At the same time narrow valleys were cut on the Kittatinny mountain and in the highlands east of the valley. The third cycle of erosion followed a second uplift. During this cycle the sub-valleys of the great Kittatinny valley, such as those of Clove river, Papakating creek, Paulins kill, &c., were developed.

The second cycle of erosion was short as compared with the first, and its work was far from complete when interrupted by the uplift which inaugurated the third cycle. The third cycle had proceeded less far than the second when interrupted by the advance of the ice of the glacial period. The work which has been accomplished since the disappearance of the last ice sheet may be regarded as a continuation of the third cycle. The amount of erosion accomplished during this cycle since the ice disappeared is trivial, when compared with that which had been accomplished during the same cycle before the advent of the last ice sheet.

The gorge which the Delaware river has cut through Kittatinny mountain at the Water Gap is the work of the Delaware river during the second and third cycles. It is sometimes cited as a wonderful example of the erosive power of a river, and it certainly is an "impressive and majestic feature of the landscape of Sussex and Warren counties."* But to one who understands the topography of this region, the long, even crest line of Kittatinny mountain, stretching away for miles to the north, and the almost equally even crest line of the highlands seen in the distance across the valley to the east, tell of a lapse of time, and of an amount of erosion, beside which the

*C. C. Vermeule, Geological Survey of New Jersey, Vol. I., "Report on Topography," p. 122.

gorge of the Water Gap seems paltry and mean. The former tell of whole plateaus of mountainous elevations reduced to a peneplain near the level of the sea, whereas the latter tells merely of the cutting of a narrow gorge through a single mountain ridge.

A. DRIFT DEPOSITS WEST OF GREEN POND MOUNTAIN.

I. THE UNSTRATIFIED DRIFT—TILL.*

Within the area defined above, the drift on the uplands, including the principal slopes as well as the summits, is usually till (ground moraine), while the drift in the valleys between the uplands is very generally stratified. Throughout the whole area, the intimate relationship between the character of the drift and the subjacent rock is well illustrated. The close dependence of the former upon the latter is more conspicuous where the till is thin than where it is thick. In a rough sort of a way the degree of dependence may be said to be inversely proportional to the thickness of the drift. To this general statement there are certain apparent exceptions, one of which is sometimes rather conspicuous. Throughout those parts of Sussex and Warren counties which lie east of the Kittatinny mountain, the bowlders are very largely from the Oneida and Medina formations, while the underlying rock is Hudson River shale and Trenton limestone. The abundance of foreign bowlders in this region is to be accounted for by the fact that the Oneida and Medina formations are much harder than the Hudson River and the Trenton, and the rock masses from the harder formations were able to suffer much wider transportation without destruction than those from the softer.

In a general way it may be said that the till is more strictly local in character than the stratified drift of adjacent valleys. This is not to be interpreted as meaning that the local formations have not made their contribution to the stratified drift. This they have done in all cases. As the stratified drift along any valley passes from one forma-

* The following generalized statements are based in large measure upon the work of Mr. H. B. Kümmel, who has also rendered important assistance in the preparation of this report.

tion to another, the new formation shows itself promptly in the sand and gravel.

The drift on the Kittatinny mountain.—On the crest of the Kittatinny mountain, the till is usually very thin. In many places it is absent altogether. Considerable thicknesses of it can be said to occur only in small patches, which are frequently much separated from each other.

Where the mountain widens to the north, there is more drift upon its summit than where it is narrow. The till is generally very stony, and large bowlders are often so numerous, even where the underlying rock is completely concealed, that most of the area has not been brought under cultivation. It is estimated that the average thickness of the drift on the crest of the mountain must be considerably less than five feet. On the east slope of the mountain there is almost none, while on the west slope its quantity is much greater than on the east face, or on the crest.

The local character of the drift is frequently well shown. On the Medina sandstone, the matrix of the drift almost up to the line of the junction of this formation with the Oneida, is distinctly reddish, showing that the Medina formation made the principal contribution to its substance. On the other hand, Oneida bowlders are very common over the Medina formation to the west, indicating that the movement of the ice was more westerly than the strike of the formations. The direction of movement thus indicated is corroborated by the striæ, as will be noted later.

It may now and then be observed along the Kittatinny mountain, that the upper part of the till is lithologically unlike the lower. Where this difference is observable, the lower part is more local in constitution than the upper, and is undoubtedly of subglacial origin. The upper layer, which is usually very thin, may have been superglacial in origin. An exposure showing these characteristics may be seen near the State line along the Port Jervis and Coleville road. It is not to be understood that superglacial drift is thought to have any considerable development in this part of the State. The occurrence of drift which can be so referred is the exception rather than the rule, and even where present, is very limited in quantity.

As a geographic feature, the Kittatinny mountain cannot be said to have been greatly modified by the ice of the glacial period.

West of the Kittatinny mountain.—West of the Kittatinny moun-

tain, the ridge which extends from Flatbrookville to Peter's valley has, in general, rather steep slopes, and is but thinly covered by drift. From Peters Valley to Brick House (Montague) the ridge is wider, its slopes are gentler, and till is more plentiful. Northeast of Brick House the drift is again thin, much of the surface having no more than a meager covering.

The crest of this ridge is made up of the Cauda Galli formation. This is flanked on the east by the Water Lime and Lower Helderberg limestones, and on the west by the Corniferous. The till may be observed to undergo changes in composition wherever the junction of the underlying formations is crossed. On the east side of the ridge the till is usually compact, as if it had been subjected to great pressure, while on the west side it is more uneven and less compact. Its apparent looseness of texture is perhaps often superficial, due to the fact that the wind has blown more or less sand upon its suface from the valley beneath.

The general geographic features of this region remain much as they were before the advent of the glacial period. The deposits of drift have been sufficient, however, to make some slight changes in the drainage of the region, by establishing new divides.

The Kittatinny valley.—In the Kittatinny valley there are two principal formations, the Hudson River sandstone and shale (slate), and the limestone. These formations appear at the surface in long belts running northeast and southwest. The surface features of the shale and sandstone areas are so unlike the surface features of the limestone belts that they may be separately mentioned.

Till on the limestone.—Where limestone is the underlying rock, the present surface is often rough, and the striking topographic features are often dependent upon the underlying rock, rather than upon the drift. The relief is not exceedingly great, but the roughness assumes a peculiar phase. In many places considerable projections of limestone appear above the drift. These may be few or many feet in height, and are remarkable both for their freedom from drift and for their irregularity of form. Looking at a considerable stretch of limestone country from a distance, the projections of rock appear as huge warts upon its surface. They are sometimes surrounded by stratified drift, and sometimes by unstratified. They are especially likely to be conspicuous in the former case, since the surface of the stratified drift is often approximately plane.

The marked roughness of the exposed surfaces of limestone is probably the result of post-glacial weathering. In no single instance was the bare limestone surface seen to retain the markings, or even the smoothing, which the ice must have given it. In some cases it is true that the projections of limestone have the general form of *roches moutonnées*, but even in such cases the surface has become markedly rough and irregular.

The peculiar warty topography for which the bare limestone projections are responsible, is especially well developed in Warren county between Blairstown and Jacksonburg, north of Cedar lake, north of Paulina, and between Blairstown and White pond, north of Marksboro. The same topography is characteristically developed northeast of White pond, extending into Sussex county, both east and west of Stillwater. It is strongly marked in the vicinity of Shuster (Warren county) and Catfish (Sussex county) ponds. Further examples are found in Warren county half a mile south of Mt. Herman, half a mile southeast of Swayze's Mills, three-quarters of a mile north-northwest of Shiloh, from Southtown northeast through Johnsonburg, and in the same direction beyond Washington (Hunt's Mills), in Sussex county. At some of these places there are high, steep ledges of limestone.

The warty topography is equally well developed at many points in Sussex county. It may be seen along the road between Swartswood lake and Swartswood station, as also south of Myrtle Grove and west of Balesville. It is well exhibited along the road between Balesville and Branchville, from one to two and one-half miles south of the latter place. The same type of topography is the rule, rather than the exception, along the two sub-valleys on the east side of the great Kittatinny valley. Particularly striking examples of it are found at many points in the timber west of Springdale school-house, and west of the large swamp between Hunt's Mills and Springdale, and in the area on the west side of the Pequest, a half to three-quarters of a mile northwest of Huntsville. Nowhere in Sussex county is it better shown than in the area lying west of Hewitt's pond and Long pond, and between Andover Junction, Springdale and Stickle pond. A good idea of it can be obtained along the road between Springdale and Andover Junction. Here the stratified beds of drift may be seen to be built up to certain tolerably definite levels against slopes of the projecting limestone ledges. On the rock surfaces themselves, there is very little drift.

It is thus seen that the warty topography is characteristic of the limestone belts as a whole. There are, however, a few localities where the limestone surface seems to be less uneven, and where the till is thick enough to effectually conceal the rock, although the present topography is primarily that of the rock rather than that of the drift. Such areas are mostly small.

Frequent sinks affect the surface of the limestone belts. In a few of them ponds occur. Some of the sinks have perhaps been formed since the glacial period, while others appear to have been deepened since that event.

A sink is seen occasionally, in the bottom of which there is an opening which allows the drainage to pass beneath the surface. A sink hole of this sort occurs about half a mile north of east of Jacksonburg, in Warren county. Into it flows a considerable stream of water, which can be plainly heard as it dashes down into its subterranean channel. Where the limestone sinks are abundant, as is occassionally the case, and where there are hillocks of drift intervening, the topography sometimes takes on something of a morainic aspect.

Such data as are available indicate that the surface of the limestone is very much rougher than the present surface; thus a well at the Jacksonburg hotel, within a few yards of a limestone ledge, penetrates over forty feet of drift without reaching its botton. This is but a single illustration of the extreme unevenness of the rock surface as indicated by data at other points.

Where the till on the limestone is thin, as is the rule, it seems to be thoroughly oxidized and leached, and the matrix of fine material is so like the residuary earth arising from the decay of the limestone, that, but for the bowlders, the two could hardly be distinguished from each other. With the exception of the bowlders, the till on the limestone must have been derived mainly from the limestone itself. The bowlders are largely of foreign origin. A large number of estimates at different points on the limestone belt, in Warren county, indicate that the various sorts of bowlders occur in some such proportion as the following:

Oneidas	50 to 60	per cent.
Medinas	2 to 6	"
Hudson River shales and sandstones	9 to 12	"
Limestones	16 to 40	"

The average thickness of the till on the limestone areas of the Kittatinny valley is difficult of estimation, but it probably does not reach ten feet.

Till on the Hudson River shale.—The topography of the Hudson River shale belts of the Kittatinny valley is markedly unlike the topography of the limestone belts. In the former, the principal agent of preglacial degradation was abrasion. In the latter, solution played an important part. The differences in the methods of wear of the two formations had resulted in somewhat different topographies before the incursion of the ice. The drift is perhaps not thicker on the shale areas than on the limestone, but the rock appears to be bare much less frequently. Even where little drift was left upon its surface, the shale has disintegrated since the retreat of the ice to such an extent as to have become covered with a thicker or thinner bed of disintegrated material. The present topography shows round, flowing contours, as against the craggy and angular forms which affect the limestone district. Very many shale knolls having the general form of *roches moutonnées*, are but thinly covered with drift, while others are almost free from it.

Locally the shale is deeply covered with till. Nevertheless the modifications of topography by the drift are on the whole so slight as to make the determination of the main preglacial features easy. As a whole, the shale area consists of a plateau, which is more or less trenched by stream valleys. The plateau-like character is well seen north and northeast of Jacksonburg. Within this region the minor streams frequently flow for considerable distances parallel to the strike of the strata, before turning across the same to join the larger valleys. Such streams have cut the plateau surface into a series of more or less well-marked ridges, having a trend parallel to the strike of the formation. Where the streams leave their strike valleys, the ridges are interrupted by narrow valleys. This ridged topography is well developed east of Beemerville. It is strongly marked also in the narrow shale belts between the first and second, and between the second and third sub-valleys within the limits of the main Kittatinny valley, southwest of Deckertown. In some places the plateau is so much dissected by longitudinal and transverse valleys that it presents the appearance of an orderly assemblage of rounded hills with something of a linear arrangement, the tops approaching the same general level.

Occasionally rounded knolls of shale are so numerous and so disposed with relation to one another as to resemble more or less closely the knolls and hillocks of a terminal moraine. This resemblance is especially noticeable where the till between the knolls is so disposed as to give rise to ponds and undrained marshes. In most such cases, however, there are at least minor topographic marks which distinguish the shale knolls from drift hillocks. There is usually some sharp projecting corner which serves to differentiate them, even judged by the criterion of form alone, from hillocks of drift. The existence of the knolls is believed to have been determined primarily by preglacial erosion, though their shapes were doubtless largely modified by the action of the ice.

The comparatively narrow shale belts which form the sharply-marked ridges between the sub-valleys opened on the limestone belts, are in general but thinly covered with drift. Along these lines the moutonnéed shale knolls and ridges give a strongly-marked undulatory topography, in which hillocks and depressions follow each other in rapid succession. Along these ridges the till is locally thick, and the topography has the long, sweeping slopes and gentle undulations of till deposits. The best example of this local development is in the vicinity of the Yellow Frame church (Hardwick church), where the three townships of Green, Stillwater and Frelinghuysen meet.

Within the shale area, the till is thickest on the shale belt lying between the Kittatinny mountain and the Paulinskill—Papakating—Wallkill sub-valley. This is especially true from Culver's pond southwest to Hardwick, in the area where the plateau-like topography is best developed. From Culver's pond southwest to the Water Gap, there are thick accumulations of till on the shale hills close up to the foot of the Kittatinny mountain escarpment; but from the north corner of Frankford township to the State line, the shale hills immediately at the foot of the mountain are nearly free from drift. Thick accumulations of till also cover the hills between Coleville and Clove brook.

Where present in any considerable thickness, the till on the Hudson River slate usually has a compact clayey matrix, containing many stones of all sizes. Sometimes it is distinctly foliated, but this was not commonly observed. Near the mountain the surface is thickly strewn with bowlders, chiefly from the Oneida and Medina ledges. Although

widely distributed, these bowlders do not, in other parts of the valley, commonly constitute more than twenty-five to forty per cent. of those which appear on the surface. The proportion is often much less.

Except near the borders of the limestone belts, the till on the shale and slate is usually not calcareous. Where limestone is present, leaching has generally removed all calcareous matter from the clayey matrix to a depth of from three to five feet.

Where rock is near the surface, it is often covered by a layer of loose material, composed chiefly of small, angular, little-worn slate or shale fragments. Foreign pebbles are sometimes found embedded in this body of local material in such positions as to make it necessary to suppose that the ice reworked the local disintegrated material of preglacial origin, added a small amount of foreign material to it, and left the whole not far from the position which most of it occupied before.

Drift bowlders from the elæolite syenite.—Northwest of Beemerville there are a number of outcrops of elæolite syenite. They occur on the face of the steep eastern slope between the Oneida ledge and the slate and shale below. The outcrops occur at frequent intervals for a mile and three-quarters along the mountain face. Since this rock is one which is easily recognized in the drift, and since its out-crops are very limited in extent, the distribution of bowlders from them cannot fail to give important information concerning the direction in which the ice moved. Generally speaking, it may be said that the bowlders and smaller bits of syenite are distributed to the south and southwest of the outcrops for a distance of about twenty miles. The area within which they were found in the drift is approximately bounded on the southeast by a line drawn from the outcrop northwest of Beemerville, south by west, to a point a mile and a quarter east of Washingtonville, thence southwestward, to a point just east of Hunt's pond, Green township; on the south, by a line from Hunt's pond nearly due west to the foot of the mountain just east of Catfish pond; on the northwest by a line along the east face of the Kittatinny escarpment. It will be observed that the area where the elæolite syenite occurs in the drift is triangular in outline, the apex being at the outcrops. The length of the triangle, as already stated, is about twenty miles. Its base has a width of about eight miles. Near the outcrops, at the apex of the triangle, the bowlders are relatively large and somewhat common. As the triangle widens to the south, the

pieces of syenite become less and less abundant, and their size smaller.

As determined by these pieces of syenite, the direction of ice movement must have been between S. 12° W. and S. 46° W., corrected for magnetic variation. These figures are in general harmony with the direction of the numerous striæ in the vicinity.

In addition to the above area in which the syenite erratics occur, a few bowlders were noted in a locality so significant as to deserve special mention. It is to be remembered that the syenite outcrops on the east slope of the Kittatinny mountain are 100 to 150 feet below the summit of the Oneida ledge. Across the mountain northwest of Beemerville, many bowlders of syenite were noted at an elevation 100 feet higher than the nearest outcrop, and due west of it. These bowlders, however, may have come from the most northerly outcrop of the syenite, in which case the line of motion was about S. 48° W. (corrected). If they came from this outcrop, they may be no more than thirty feet higher than their source, but to reach their present position they must have passed over a hill about 100 feet higher than their parent ledge.

Along an abandoned road across the mountain, three-quarters of a mile northwest of Beemerville, a number of syenite bowlders were found on the west slope of the mountain. They lie S. 62° W. to S. 69° W. (corrected) of the northernmost outcrop, and a mile from it. There are no high hills between their present position and the syenite outcrop. A short distance east of north of the outcrop, and just west of the crest of the mountain, striæ were found which have a direction S. 93° W. (corrected), or three degrees north of west. This observation, together with many others which will be noted later, as well as the distribution of the syenite bowlders on the west side of the crest of the Kittatinny mountain, prove conclusively that in this vicinity the direction of ice movement was more to the west than the trend of the Kittatinny mountain, and that the ice passed from the Kittatinny valley over the crest, and out to some extent on the western slope. Syenite bowlders, however, were not found on the west slope, except where mentioned.

The till of the highland area.—On the gneiss highlands east of the Kittatinny valley, and west of the Green Pond mountain, the drift is mainly till. On the steep slopes it is usually thin, becoming more abundant wherever the slopes become more gentle. It reaches its

greatest thickness on the more level summits, and in the cols of the various ridges.

Throughout the area exposures of rock are somewhat frequent. Where the rock is not covered by drift, it is not because the ice did not cover it, but because the ice failed at some points to make deposits of drift. There are relatively few exposures of drift. Data concerning its thickness and the details of its distribution are therefore not abundant. It is estimated, however, that the drift for this region has an average thickness of from ten to twenty-five feet. The greatest known thickness inside the moraine is 100 feet. This is near Ogdensburg.

The surface of the gneiss and schist beneath the till is often smooth and polished. It is the exception rather than the rule to find it decayed. In such cases it is to be presumed that the ice did not wear off the material which was decayed at the time of its incursion, for the amount of decay which has taken place since the last incursion of the ice is, in general, exceedingly small.

With few exceptions, the till covering the gneiss west of Green Pond mountain is composed mainly of gneissic material. In its typical development it consists principally of a greyish, sandy or clayey matrix, in which are set bowlders and pebbles of gneiss, varying in size from a fraction of an inch to several feet in diameter. The gneiss material frequently constitutes as much as ninety-five per cent. of the whole body of drift. The gneiss bowlders are, on the whole, considerably worn, but do not often show well-developed striæ. The drift also carries some limestone, Hudson River slate, shale and sandstone, as well as occasional bowlders which probably came from the Oneida or Medina formations further north. There are also occasional constituents from other formations, which are not easily identified.

The only area where shale or slate occurs in quantity in the drift of this region is east and northeast of Lake Hopatcong, as far north as Oak Ridge. Its presence in this locality is easily accounted for by the existence of a shale or slate formation *in situ* between Oak Ridge and Milton, at the west base of the Green Pond mountain. Limestone does not abound in the drift of the area under consideration except in its western part, near the limestone formations of the Kittatinny valley. The movement of ice in this region seems to have been somewhat more to the south than the strike of the formations

and the limestone was therefore carried out on the crystalline schist area to the east.

It is a point of some interest that Green Pond mountain conglomerate does not appear to have been carried on to the highland area, west of the Rockaway river. Material from this formation has been found in the moraine near Rustic, which is in line with that part of the Rockaway river which is parallel with the Green Pond range. Further west there are occasional bowlders which closely resemble certain quartzites found in the Green Pond mountain formation, but none seen could be referred with certainty to this formation.

The surface of the till is generally oxidized and leached to such an extent as to be distinctly noticeable to a depth of two or three feet from the surface.

Drumlins.—West of the Green Pond mountain range, drumlins are exceedingly rare, if present at all. There is only one locality where they are even suspected of existing. Between Franklin Furnace and Hamburgh there are five hillocks which in general outline closely resemble drumlins. The longer axes vary from 600 yards to three-quarters of a mile. The heights vary from 44 to 128 feet. Their slopes are smooth and regular, and in their outline there is nothing to indicate that rock is near the surface. Their longer axes are parallel to each other, and approximately parallel to the direction of ice movement. In all these respects they resemble drumlins, but it must be remembered that the direction of ice movement in this vicinity is approximately the same as that of the strike of the formations, so that their position cannot be regarded as proof that they are drumlins. They may be nothing more than veneered hills.

RECESSIONAL MORAINES.

Within the area of Sussex county there are some minor moraines which appear to have been made during halts of the ice, in the course of its general recession. A somewhat well-defined recessional moraine extends from Ogdensburg to Long pond, near Culver's Gap, though it is interrupted for short distances at several points, especially where it crosses high ridges. It passes by lake Grinnell (Lane's pond), Lafayette, Washingtonville, Balesville and the north end of Long pond (Frankford township). The moraine cannot be traced

across the Kittatinny mountain, but in the Flatbrook valley, a mile above Layton (Centerville), and again in the Delaware valley, near the Fisher school-house, there are local but well-defined morainic bodies. Their real nature is shown not less by their topography and constitution, than by their relation to the gravel plains to the south. These small morainic bodies in the Flatbrook and Delaware valleys are probably to be correlated with the Long pond-Ogdensburg moraine, although there is considerable interruption across the mountain.

The average width of this moraine is perhaps half a mile. Locally, its width increases to nearly a mile, and for considerable stretches it is not more than a quarter of a mile. The fact that the moraine is developed in the valleys, and not on the tops of the ridges between them, indicates that it was made during the closing stages of the glacial epoch for this region, when the ice had lost much of its thickness. In this condition, it seems to have retained sufficient vigor of motion to accumulate considerable quantities of drift in the valleys, while it was too thin and too lifeless to accomplish much upon the crests of the hills and ridges.

The characteristic topography of this recessional moraine is not, on the whole, very strongly developed, though it is usually distinct. Like the larger terminal moraine to the south, it is usually more stony and bowldery than the adjoining ground moraine. Locally, the till of the moraine is as clayey and compact as any found outside the moraine belt.

This moraine is here and there bordered by overwash plains of gravel and sand, while in the proper relations, gravel trains occupy the valleys below it.

When the course of the moraine between Ogdensburg and Culver's Gap is studied in relation to the topography of the region, it is seen to bend southwestward something like three and a half miles in crossing the broad Kittatinny valley. The moraine belts in the Delaware and Flatbrook valleys lie several miles north of the west end of the continuous portion of the moraine at Long pond. The more northerly position of the morainic bodies west of the mountain is easily understood, in view of the fact that the ice was moving somewhat more to the west than the course of the Kittatinny mountain, so that the latter stood as a great barrier in the way of the movement which was supplying at least a part of the ice which developed the moraines in the Delaware and Flatbrook valleys. The disposition of the

morainic bodies throughout affords an illustration of the general fact that topography influenced the position of the edge of the ice, and that the ice extended further southward in depressions than on the intervening uplands.

At several other points small patches or narrow belts of moraine-like drift occur, but none of them have any considerable development. It is possible that some of the more or less isolated morainic patches were accumulated at the same time, but so far failed of continuous development as not to make their connection evident. The most considerable of these local areas of morainic character lies west of Kittatinny mountain, just east of Brick House (Montague).

II. STRATIFIED DRIFT—MAINLY IN VALLEYS.

It has already been stated that the stratified drift of the northwestern portion of the State is confined principally to the valleys. In the valleys, stratified drift predominates. It possesses certain features which are not common to stratified drift outside of mountain regions—features which throw much light on certain phases of glacial history. These peculiarities are believed to have sprung from the existence of stagnant or nearly stagnant ice in the valleys after the ice sheet, as such, had left them, and while the stratified drift was in process of deposition. Reference was made to this class of deposits in the last annual report.

At all stages of the ice period, the ice was thicker in any given valley than on the highlands on either side. When dissolution of the ice sheet set in, the ice disappeared first where it was thinnest. Thus, in any given region, the uplands were freed before the intervening valleys. Ice tongues, or ice masses, therefore, occupied the valleys for some distance below the real edge of the ice sheet.

Ice tongues are believed to have occupied the valleys also, in advance of the main sheet, while the ice was advancing. But the behavior of the valley ice in the two cases may well have been essentially dissimilar. While the ice sheet was advancing, the valley ice was active. It constituted valley glaciers. While the ice sheet was in process of dissolution, the valley ice was inactive, and, in some cases at least, actually disconnected from the main body of ice to the north.

Disconnected ice blocks similar to those which are believed to have

lingered in the valleys of northern New Jersey were seen by the writer just below the Argentier glacier in Switzerland, in 1887. The glacier was then receding. Masses of ice had been separated from the body of the glacier, as the latter melted, and, being partially protected by debris, seemed likely to endure for a considerable time.

In the Delaware valley.—The essential facts concerning the stratified deposits along the Delaware from the moraine near Belvidere to Port Jervis may be summarized as follows: They consist of materials ranging from fine sand and silt to bowlders, even bowlders several feet in diameter. Exposures are rather meager, but gravel appears to predominate over sand and silt, though the predominant material at the surface is sand or sandy loam. The alluvial plain is almost uniformly covered with a greater or less thickness of fine silt or loam. The same is generally true of the post-glacial terraces where such exist, and is locally true of the highest terraces, representing the surface of aggradation by glacial drainage. Cobbles and stones of larger size are much more commonly present on the surface of the higher terraces than on the lower. This is sometimes true even where the body of the material is fine.

The stratified drift along the valley is plainly of glacial origin. This is shown not only by the glaciated stones which are sometimes found in it, but by the constitution of the material itself. The material of the lower terraces has been more or less worked over by the river in post-glacial time.

One of the most significant facts in connection with the stratified drift of this part of the valley is the fact that it stands in no intimate genetic relationship to the stratified drift below the Belvidere moraine. From Belvidere southward, the glacial gravel deposits of the valley decline regularly, after the normal fashion of valley trains heading in moraines.* The inclination of the surface of the terrace is especially high just below the moraine, as is the rule in valley trains. The average decline of the terrace for two miles below the moraine is at the rate of about 30 feet per mile. Just below the moraine the gravel rises to a height of 440 feet† A. T. Instead of continuing to rise steadily to the north, the surface of the valley gravel deposits falls to a considerably lower level above the moraine. Just north of Belvidere, near the river, the highest terrace has a height of only 330 feet, an

* See Annual Report for 1892, pages 115–125.

† All figures as to altitude are taken from the topographic maps.

elevation more than a hundred feet lower than that of the stratified valley drift on the other side of the moraine. There is the best reason for believing that no higher terrace ever existed in this locality. The relationships are such as to make it clear that the stratified drift deposits of the valley above Belvidere and below, were not strictly contemporaneous. The gravel deposits below Belvidere were made by waters issuing from the ice when its edge occupied the position which is now marked by the moraine. At this time the Delaware valley above Belvidere was filled by ice, and gravel deposits were not there making.

There are well-developed terraces of stratified drift at various points from Belvidere to the State line, but not only do they not correspond in altitude with the gravel terraces below the moraine, but they are discordant among themselves. Not only this, but the discordance is not to be attributed to post-glacial erosion. It is original, not secondary.

As the ice receded northward from the position of the moraine, the waters arising from its melting coursed through those parts of the valley successively freed from ice. These waters deposited sand and gravel, especially just beyond the edge of the ice at each successive stage. Since the ice withdrew from south to north, the gravel just north of the moraine, or at least much of it, was deposited before that of the valley still further north. This general relation holds up to the north line of the State and beyond. The valley gravel was largely deposited in sections, so to speak, commencing at the south.

A study of the terraces above Belvidere shows that two somewhat distinct stages in the retreat of the ice may be made out with some degree of certainty. Just below the recessional moraine, near the Fisher school-house, the gravel terrace rises rapidly to meet it. This is the relation which usually holds south of a moraine. Both the moraine and the gravel below it, and particularly their relation to each other, show that the ice edge halted in its retreat along the line now occupied by the moraine. The terrace below the moraine is higher than that for some distance above, just as at Belvidere.

The second stage in the recession of the ice is marked by the rise of the terrace to an altitude of more than 500 feet, a short distance below Brick House (Montague), near which point there is a second subordinate recessional moraine. While the moraine is not conspicuously developed across the Delaware valley, it is well defined just east of Montague.

In the Delaware valley there is relatively little gravel disposed in such wise as to indicate that the drainage which deposited it was interfered with by the presence of ice while deposition was going on. At a few points only is there evidence that stagnant ice masses occupied the valley while drainage coursed through it, and that the gravel was deposited about them. The general freedom of the valley from stagnant ice while the deposition of stratified drift was taking place, is in striking contrast to the condition of things in the Flatbrook valley just to the east. The difference is perhaps to be accounted for by the fact that drainage was more vigorous through the larger valley than through the smaller.

In the Flat brook valley.—The Flat brook valley, which has a course essentially parallel with that of the Delaware from Flatbrookville to Montague, contains a very considerable body of stratified drift, which in many respects is in striking contrast with that of the Delaware. The deposits in this valley are among the most complex and interesting in the northern part of the State. Their especial feature of interest is the peculiar topography which they possess, due principally, it is believed, to their deposition about bodies of stagnant ice which lay in some parts of the valley after the main ice sheet had melted from the adjacent highlands. While this ice still occupied the valley, drainage from the ice a little further north coursed through it, bearing and depositing the stratified drift about and among the ice masses. This valley ice was probably in connection with the ice sheet at some points, and separated from it in others while deposition was going on. In the former case, it was perhaps not altogether without motion at the time the sand and gravel were deposited about it, though the movement may have been so slight as to have had little effect on the deposition. Even where the valley ice was not stagnant at the time the stratified drift was deposited about it, it became so before its melting. Its final influence on the disposition of the drift was therefore that of stagnant ice. On the other hand, some of the valley ice appears to have been in the form of isolated masses at the time the deposition took place. These masses were sometimes buried completely by the sand and gravel. When the ice melted the gravel deposits took the peculiar forms which they now possess. Wherever isolated blocks occurred, either buried by gravel, or completely surrounded by it, their melting gave rise to depressions. Where the masses of ice were very considerable, and especially where they were thick, their melting

often allowed the gravel which had been deposited about them to slump down into the depressions made by their melting. In other cases, the irregularities of the ice appear to be reproduced in reverse in the surface of the deposits made against it.

Good developments of the rough topography which characterize deposits made against stagnant ice may be seen about two miles above Flatbrookville. Here sharp-winding ridges, thickly strewn with pebbles, inclose irregular hollows, forty to fifty feet deep. The topography is that of a perfect network of irregular ridges, which branch and cross in the most confused manner. The highest of the ridges and knolls at this point reaches an elevation of 448 feet, an altitude which accords approximately with the height of the gravel deposits further down the valley, where they take on the form of normal stream terraces.

In spite of the roughness of the topography at the point mentioned, it is clear, when studied in connection with its surroundings, that even here there was a tendency, at the time it was developed, to build up the stratified drift to a certain definite aggradation level. This tendency was opposed and its consummation prevented by the presence of the ice blocks along the valley. Stagnant ice forms are also well developed on the left side of the valley, a mile or so south of Peters Valley, and again on the west side of the valley just south of the village.

The stratified deposits which were influenced by stagnant ice often assume the general form of terraces. These terraces differ from normal river terraces primarily in the fact that the slopes which face the axis of the valley are not erosion slopes. They are often extremely irregular, the irregularities being of the sort which characterize kame areas. The upper surface of the terrace is likewise often obscured by a more or less kame-like topography. Such terraces have been termed *kame terraces.** The terrace form of the valley deposits made about stagnant ice often appears only when they are looked at in a broad way. It is then seen that, rough as the surface may be locally, there is a somewhat definite upper limit to the whole series of deposits, and that this surface declines in the direction of glacial drainage. On the upper surface, the roughness is due principally to a greater or less abundance of depressions below the upper level. Where stagnant ice was very abundant, and in isolated masses, the

*Annual Report for 1893, page 156.

depressions are very numerous or very large. Where stagnant ice was at a minimum, the upper surfaces of the terraces are more nearly plane.

A form of topography characteristic of this valley and of stagnant ice deposits in general is the following: A broad and somewhat swampy flood plain in the axis of the valley is bordered on one or both sides by a strongly-marked kame belt a few rods in width. This kame belt is lowest near the axis of the valley. It rises in the opposite direction, and finally grades into a flat-topped terrace, which extends to the side of the valley. Examples of this combination of forms are found, 1°, north of Wallpack Center, on the west side of the brook; 2°, half a mile south of Layton, on the east side; and, 3°, on the west side of the brook just below the second moraine, about two miles southeast of Montague. Large, flat-topped kames, in some cases probably representing the deposits made in ponds in the ice, occur, 1°, east of the millpond a mile south of Peters Valley; 2°, between Peters Valley and Layton, and, 3°, north of the second moraine, between the headwaters of Flat and Mill brooks.

The stratified drift of this valley is hardly less singular in its distribution than in its topography. In some parts of the valley it forms a belt a quarter to an eighth of a mile in width, while in others the belt is nearly a mile wide. Its width does not stand in any necessary relationship to the width of the valley. Where the valley is wide, the flood plain may be wide, and nearly free from drift, while the bordering terraces are narrow. Close at hand, the flood plain may be narrow, while the terrace plain is wide. The stratified drift has the greatest areal development in the middle course of the valley.

The extreme variability in the width of the belt of low land along the stream is not less notable than the variations in the width of the belt of stratified drift. Thus for four or five miles above Flatbrookville the flood plain is very narrow. It then widens somewhat suddenly, having in some places a width of half a mile; but from these very considerable widths it sometimes narrows suddenly to a few rods, or even disappears altogether. These sudden contractions in the width are sometimes due to the fact that a great spur or ridge of gravel, or a line of kames, juts out from one side of the valley and extends across it to the opposite side. This may be seen a mile and a half below Peters Valley, as well as at other points further down the stream.

Where the flood plain is wide, the gravel terraces on either side of it do not usually possess erosion slopes. The slopes are marked by knolls and small hollows, showing clearly that the depression whose bottom is marked by the flood plain, is not the result of post-glacial erosion. Where a wide part of the flood plain has but little length, as is frequently the case, its whole area represents the bottom of a very considerable depression in the midst of stratified drift, the only outlet being the narrow gorge through which the stream flows. In such cases it is clear that a great mass of stagnant ice occupied the site of the depression, and that the gravel was deposited about it, and especially between it and the bluffs on either hand. This may be seen east of Peters Valley. The same phenomenon is repeated again and again in the course of the valley. The masses of ice which occupied such positions were frequently very irregular, as shown by the topography and outline of the gravel and sand deposited about them.

That there was a tendency toward the development of an aggradation level in this valley, in spite of the stagnant ice, is shown by the considerable stretches of kame terraces which occur at a few points, and also by a comparison of the elevations which the gravel reaches in various parts of the valley. Thus in the vicinity of Flatbrookville the surface of the gravel has an elevation of about 420 feet; two miles above, 448 feet; at Wallpack Center, six miles above, 449 feet; at the millpond, eight miles above, 476 feet; at Peters Valley, 490 feet; at Layton, 550 feet; at the moraine a mile above Layton, 620 feet; near Hainesville, 640 feet; at the second recessional moraine above Hainesville, 740 feet; at the kame terrace north of the moraine, 640 to 660 feet. (Plate I., Figure 1.)

History of deposition.—The altitude of the terraces in the Flat brook valley shows several important facts: (1) The gradient of the terraces themselves is *less* than the gradient of the present streams. This is shown in Figure 1, Plate I. This is the reverse of what is found along most streams. An explanation may be found in the conditions prevailing when these deposits were formed, and since. When the deposits were made, the Delaware was flooded, and the height of the terraces at the mouth of the Flat brook, was determined by the height to which the Delaware terraces were built. The cutting in the lower part of the Flat brook has kept pace with the cutting in the Delaware, but under the present conditions of precipitation, slope and load, the stream has not lowered the upper part of its valley at an equal rate.

(2) From a point about two miles above Flatbrookville, to Wallpack (four miles), the aggradation level is nearly horizontal (*b c*, Figure 1, Plate I.) From Wallpack Center, the terraces rise northward by a gradient which increases very rapidly (*c d*), as the moraine (*d*) a mile north of Layton is approached. The rise is seventy feet for the last mile. With the increase of gradient, there is a marked increase in the size of the materials composing the terrace. These relationships clearly show that the moraine above Layton represents a halt in the ice retreat, during which time the gravel deposits, certainly as far south as Wallpack Center, were formed. The topography of these deposits, and the wide, swampy flood plain in the axis of the valley, show that more or less ice lingered in the center and bottom of the valley during the period of deposition, and that the deposits were made around and between the ice blocks.

(3) North of the moraine, above Layton, the gravel terrace is ill-defined for some distance, but the gravel appears to be somewhat lower than just south of the moraine. From this point the terraces ascend with increasing gradient (*e f*,), to the second moraine (*f*), three miles above Hainesville, where the elevation is 740 feet. This moraine represents a second pause in the ice retreat, during which the gravels between the first and second moraines were deposited around the blocks of ice which still lingered in the valley. During this time it was probably true that more or less sand was carried down the valley below the Layton moraine, but the greater part of the drift below Layton appears to have been deposited earlier.

(4) North of the second moraine is a kame terrace and kame area, 100 feet lower than the moraine (*g*). This rises to the northward (*g h*). Its position, its elevation and its topography show that it was formed after the ice had withdrawn somewhat from the second moraine. The behavior of the gravel in the vicinity of the recessional moraine is in perfect keeping with the phenomena in the Delaware valley in the vicinity of Belvidere. The relations of the stratified drift above and below the secondary moraines are such as to show that there was a distinct break in the deposition of the valley drift above and below them.

The stratified drift of this valley has not the loose texture which prevails in similar deposits in some other regions. The character of the formations which gave rise to the materials, afforded much clayey matter. Indeed, the surface of the stratified drift is often distinctly

clayey. The fine earthy matter of the surface represents the last phase of deposition of the glacial waters. In addition to this, it is probable that some of the clayey matter has developed since the drift itself was deposited. Much of the drift is composed of slate and shale, which, on disintegration, gives rise to close-textured earth. The surface of the stratified drift in this valley is often so clayey that, were it not for exposures, the material would never be suspected of being principally sand and gravel.

In the Mill brook valley.—The Mill brook valley is really a continuation of the Flat brook valley northeastward to the State line. The general phenomena of the Mill brook valley are comparable to those of the valley of the Flat brook. There are more or less discontinuous terraces along the valley, rising from 60 to 140 feet above the stream. The gravel deposits frequently show forms characteristic of stagnant ice deposits, and are frequently altogether independent on opposite sides of the valley. This is true, even where the differences can be shown not to be the result of post-glacial erosion. This independence of levels is well shown on the opposite sides of the small brook which joins the Mill brook half a mile south of the State line. According to the topographic map, the gravel reaches a height of 660 feet on one side, while on the other it stands about 100 feet lower. The independence of the deposits on opposite sides of the valley is still further shown at some points by their presence on one side and their absence from the other, and this where the absence cannot be attributed to subsequent erosion. In the valley of Mill brook no general aggradation level can be made out.

In the Big Flat brook valley.—Phenomena similar to those of the Flat brook and the Mill brook valleys are found in the valley of the Big Flat brook. The sudden widening and narrowing of the alluvial plain, the kame-like surfaces, and the irregularity of the stratified deposits in general, are in keeping with those of the main valley to which this subordinate valley is tributary.

In the valley of Paulins kill.—Deposits of stratified drift made by glacial drainage are very generally present in the valley of Paulins kill. From Stillwater to Blairstown, a very considerable part of the glacial drainage appears not to have followed the course of the kill, but to have followed a more northerly course by White pond, and thence down Blair's creek. It entered Blair's creek in the vicinity of Hardwick Center. Northeast of this point, the drainage found its way by

an irregular course among the hills. The phenomena along this line of drainage correspond with those along the valley of the kill.

More or less stagnant ice was present in the Paulins kill valley during the deposition of its gravels. This is shown—1°, by the various types of kame and kame terrace topography; 2°, by the wide, swampy flood plain, which is not the result of post-glacial erosion; 3°, by the occasional outcrops of rock near the bottom of the valley below the level of the gravel deposits, but in positions where post-glacial erosion could not have discovered them; and, 4°, by the kettle-like depressions in the steep slopes of the terraces where they rise above the flood plains.

The ice did not linger in all parts of the valley to an equal extent, and in some localities the deposits were made in comparative freedom from ice interference. Well-marked kames, kame terraces and other stagnant ice forms occur—1°, near Hainesburg; 2°, between Blairstown, Jacksonburg and Kalarama; 3°, near Swartswood station; 4°, a mile northeast of Swartswood station; 5°, a mile southwest of Balesville; and, 6°, between White and Shuster ponds along a branch drainage line. Above the moraine belt at Balesville the kame topography is marked at points some distance back from the stream, whereas along the kill the deposits form a low, level, broad terrace. This latter was probably formed later than the kame terraces, and after the ice had disappeared from the valley.

Broad terraces, showing little influence of the ice, occur—1°, above Columbia; 2°, at Walnut Valley; 3°, above and below Stillwater; 4°, between Augusta and Branchville; and, 5°, east of Augusta. The general level of the broad plain at Walnut Valley is forty feet or more below the highest level (380 feet) of the gravel in the vicinity, and the plain south of Stillwater is also about the same amount below the highest aggradation level. They cannot, however, be considered as secondary post-glacial terraces of degradation, as all the data go to show that the erosion along the kill has been little.

The accompanying profile (Figure 2, Plate I.) shows the elevation attained by the highest terraces, as well as the present slope of the stream. It must be understood that the terraces do not at all points reach this maximum height. The most important of the localities where they fall below the general level for considerable distances are indicated. As shown by this profile, the upper limit of the gravel rises from Columbia, to a point a mile and a half above Hainesburg

(*a b* on the profile), where a maximum height of 380 feet is reached. Then for two miles, in the vicinity of Walnut Valley (*b c*), the gravel does not appear to reach higher than 370 feet, and the general level of the broad Walnut Valley plain is less than 350. Near Kalarama, it again reaches an elevation of 380 feet, and ascends by a very constant gradient of about fifteen feet per mile, to an elevation of 470 feet a mile above Marksboro (*c d*). For the latter half of this distance the valley is narrow, and only occasional patches of gravel are present. For two miles below Stillwater, the gravel deposits are abundant, but most of them are at a low level (440 feet or less, *d e*). Here and there traces of gravel appear at elevations of about 460 or 470 feet, the proper aggradation level. Near Stillwater (*e*), the terraces rise by a somewhat abrupt slope from 440 to 460 feet, and then less rapidly to 480 feet. Near Middleville (*f*), the gravel attains a height of 500 feet, but a little further up stream, according to the topographic map, it does not rise higher than 480 feet. For some distance above Emmon's station, the gravel is absent entirely, but when it again appears it has an elevation of 500 feet or more (*g*). From this height it rises to about 540 feet (*g h*), in front of the moraine (*i*) near Balesville.

North of the moraine there are kame terraces at 540 feet (*j*) back from the stream, though along the stream the terrace has an elevation of only about 500 feet. The high-level gravels disappear near the almshouse, a mile northeast of the moraine, but the 500-foot terrace continues up the kill nearly to Lafayette (*k n*). This terrace also extends up the tributary to the kill to Branchville (*k l*), where it reaches an elevation of 550 feet. This same low terrace (*k m*) extends northeast from Augusta to the small moraine (*n*) below Frankford plains. The line *s t* shows the gradient of the kill from the Delaware to Lafayette. The line below *k l* and parallel to it represents the gradient of the Branchville tributary to the kill.

History of deposition.—From the profile of the higher terraces, something can be made out as to the stages of deposition of these deposits. The Balesville moraine marks a pause of considerable length in the retreat of the ice. The apparent interruptions in the regular gradient at Walnut Valley (*b c*) and below Stillwater (*d e*) may be due to earlier and less clearly marked pauses, though this is not certain. The high-level kame terrace above the moraine, and near the alms-house (*j*), was clearly built around ice blocks, and is

later in origin than the moraine. The lower terrace (k, n) has but little of the stagnant ice topography, and was formed later than the higher terrace, and after the ice had mostly disappeared from this part of the valley.

The small moraine northeast of Augusta marks a second stage in the history of the valley deposits. Reference to the further stages of deposition along this sub-valley will be found below in connection with the stratified drift of the Papakating.

Constitution.—The gravel of the Paulins kill valley is made up chiefly of shale and limestone, with varying quantities of Oneida and Medina pebbles. The percentage of shale and limestone varies according as the stream flows on the one or the other formation. Much of the gravel is clayey, rather than loose and sandy, and the surface is not infrequently till-like. Good exposures are found between Columbia and Hainesburg, along an incompleted railroad grade; at Blairstown; along the railroad above Marksboro and at Stillwater, in the abandoned railroad cut.

In size the material varies from sand to large cobbles. The fine and coarse material is in general more or less indiscriminately interstratified, although there are localities where the one or the other predominates. There is no marked diminution in the size of the material towards the lower end of the valley.

In the valley of Papakating creek.—In the upper part of the Papakating valley there is little stratified drift. Where the stream turns from a southerly course to a northeasterly one, it enters the strike valley, which is really the continuation of the valley occupied by the Paulins kill from the Delaware to Augusta. Here there is a very considerable body of stratified drift. This continues northeastward, with some interruption, to Deckertown and beyond.

That the gravel deposits of this valley were made when ice filled its center and lower parts at many points is shown—1°, by the topography of the deposits; 2°, by their position, high on the sides of the valley much above the stream; 3°, by the wide and somewhat swampy flood plain, which is not of post-glacial origin; 4°, by the bare outcrops of rock and the deposits of till along the bottom of the valley below the gravel deposits, where their surroundings are such as to forbid the supposition that erosion has removed overlying stratified deposits. All data point to a minimum of erosion along the Papakating since the ice disappeared. The stream has been engaged rather in filling the hollows left by the ice.

At Frankford Plains, a mile and a half northeast of Augusta, there is a well-developed gravel flat which appears to be a delta. This is indicated by the surface, and more particularly by the nature of the frontal slopes of the plain. They are steep and lobate, and their topography is not the topography of erosion. It is believed that a little lake or pond must have existed here at the time the delta was developed. A small moraine crosses the valley just below Frankford Plains, a mile or so northeast of Augusta, and this may have served as the barrier which held the lake on the south side. Through this moraine there is now a narrow erosion channel, which may have been developed in post-glacial time. To the west and northwest, the pond was probably held in by the shale hills. The gravel is deposited against the hills in such wise as to indicate that this was the fact. On the southeast, east and northeast, it would appear that the pond was held in by ice. The material for the delta was supplied by drainage from the ice to the northwest.

In the Papakating valley there are some very pronounced kames just east of Papakating station, and still others a little further up the stream a half a mile or so east of the delta at Frankford Plains. There are well-developed kame terraces along the west branch of the Papakating in the vicinity of Beemerville and Plumstock.

The profile of the deposits in this valley is shown as a continuation of the Paulins kill deposits. (Figure 2, Plate I.) The Papakating valley drains northward. As the ice retreated northward, and *down* this valley, the drainage must have either been, 1°, towards and under the ice (very improbable); or, 2°, ponds must have been formed in the valley in front of the ice, the drainage escaping to the south.

As shown above, the facts indicate that a large part of the valley was filled by stagnant ice. Ponds, if formed, must have been long and narrow, and in general situated between the ice which occupied the axis of the valley and the sides of the valley itself.

With the exception of the delta at Frankford Plains, the topography of the high-level deposits does not indicate that ponds had any considerable development. As shown by the profile, the aggradation level from Frankford Plains to the high terraces southeast of Woodbourne rises slightly (from 525 to 540 feet in six miles), though over much of this distance the gravel deposits do not reach this level, whereas there are well-marked kames and kame terraces at 450 feet, 470 feet and 480 feet (*q r*), according to the topographic map.

History of deposition.—The following interpretation may be put upon the aggradation levels of the highest terraces: 1°, a stage of comparatively rapid retreat of the ice from the position of the moraine northeast of Augusta to a point a little above Papakating (Pellettown), followed by the formation of the deposits between these points (*p o*) at elevations of 525 to 531 feet; 2°, a probable second stage of rapid retreat, and then a pause, during which the deposits from near Roy's station to near Woodbourne were formed, represented by the aggradation level from 450 feet to 540 feet (*q r*). The rapid rise from 450 to 540 may be accounted for by the material brought down the little Papakating at this point (*r*). As will be seen later, deposits at levels accordant with this extend up the Little Papakating for some distance above Woodbourne.

The stratified drift of the Clove river valley, running north from Deckertown, corresponds in general character with that of the Papakating valley. The kame terrace and kame type of valley drift is shown with special distinctness a mile or so north of Deckertown.

In the valley of Beaver brook.—The stratified drift of Beaver brook, which joins the Pequest a little above Belvidere, is usually disposed in the form of normal terraces, rather than in the form of kame terraces. Rarely does the drift of this valley behave itself in such wise as to indicate that standing ice occupied the valley to any considerable extent at the time it was deposited. Here and there, however, its presence is indicated.

In the Pequest valley.—The stratified drift along the Pequest river is more extensive than along any other valley of northwestern New Jersey. It was formed under varied conditions. In many instances, the forms and the disposition of the stratified drift are so characteristic that the history of its deposition can be readily made out. The accompanying profile (Figure 3, Plate I.) gives a generalized view of the relations of the deposits and the present drainage lines from Danville northeast to Deckertown. This profile aids much in obtaining a clear understanding of the history of deposition.

Below Danville, the terminal moraine occupies much of the valley to the Delaware. Between Pequest Furnace and a point a mile south of Townsbury, the moraine lies to the north of the valley. Previous to the formation of the moraine, a tongue of ice projected down the valley beyond Pequest Furnace to Oxford Furnace or beyond. As this ice tongue melted, and while it still occupied a part of the valley,

the gravel deposits between Oxford Furnace and the moraine were formed. Stagnant ice forms are more or less well developed. The most characteristic are the high, terrace-like ridges near the Warren county poorhouse, one and three-quarter miles south of Townsbury. These were probably formed in a crevasse in the ice. All the stratified deposits north of the moraine are slightly later in origin than these gravels.

At Danville the moraine formed a dam across the valley at an elevation of about 550 feet. The result of this dam was the formation of a lake north of the moraine, at a height of about 550 feet. This lake occupied the area of the Pequest meadows and the Quaker Settlement as far northeast as Tranquility. Its maximum length was about eight miles and its greatest width two. Its depth probably did not much exceed thirty feet. The humus and alluvium of the Pequest meadows (*a b*), at an elevaion of 514 to 525 feet, are the deposits made in the deeper parts of this lake, the humus being formed chiefly after the outlet across the moraine had been so far cut down as to transform the lake into a swamp. At the Quaker Settlement (*b c*), the deposits consist of silt and fine sand, having an average elevation of about 550 feet, or a little less. These are the shallow-water deposits made by the glacial streams. When these deposits were made, the ice had withdrawn some distance to the northward, and even the isolated ice blocks had practically disappeared from this immediate region.

In this area there are some gravels which belong to a somewhat earlier period. Small kames of coarse gravel and sand rise to heights not exceeding twenty feet above the general level of the fine sand deposits. These kames are of a totally different lithological constitution, and are much coarser than the lake deposits. They must have been made under entirely different conditions. The size of the constituents of these gravels, their poor stratification, their slight wear, and their topographical relations, indicate that they were deposited before the sands and silts which surround them, at a time when the ice was in the immediate vicinity. In addition to these kames, knobs of limestone, practically bare of drift, rise above the general level of the plain.

Towards the upper limit of the Quaker Settlement plain, as the surface approaches an elevation of 550 feet, the sand and silt grade into fine gravel, and stagnant ice forms are found. They are here less strongly marked than farther up the valley.

The glacial drainage which poured into the Pequest meadows lake entered from two main lines. One was along the valley extending from Germany Flats southwest through Andover Junction and Huntsville, to the Pequest river. In places this main channel was split up into several subordinate ones, connected by cross-lines of drainage. The other main line was along the valley extending southwest from Newton to Hunt's Mills, and down the valley of Bear creek through Johnsonburg. These two main belts of stratified drift are connected by a cross-belt between Springdale and Huntsville. The profile (Figure 3, Plate I.) follows the main line first mentioned.

As is shown by the profile, the deposits rise regularly and gradually from an elevation of about 550 feet at the upper edge of the Settlement, to a height of 615 feet or more near Huntsville (*c d*). Just above Huntsville, the higher terrace (615–620) plays out against the hillside, but above Brighton a new, broad terrace level begins at an elevation of 583 feet. This level extends north through Springdale, and passes into the plain southwest of Newton (630 feet). The same level also extends northeast to Germany Flats (*e f*), rising steadily in that direction.

The ending of the higher level (*c d*) near Huntsville and Brighton, and the beginning of the lower terrace (*e f*) just north of Brighton, point to two stages in the formation of these deposits. During the first stage, the gravel below Brighton and Huntsville was deposited. Sufficient ice remained in the valley to hold the glacial waters to an aggradation level rising to 615 or 620 feet just above Huntsville. At a somewhat later period, melting had progressed further, and the glacial streams built the terraces and plains stretching north and northeast of Brighton at a slightly lower aggradation level. There is nothing in the nature of a recessional moraine at the point where the interruption occurs, such as has been formed in some of the other valleys where distinct stages of deposition can be made out.

According to this interpretation, the gravel deposits (*b d*) from Brighton and Huntsville to the Pequest meadows, are contemporaneous. Those of the Settlement (*b c*) were lake deposits, and those between the Settlement and Brighton (*c d*), the deposit of rapid glacial streams. The kames rising above the silts of the Settlement belong to a slightly earlier time.

The second aggradation level (*e f*) rises from an elevation of 583

feet near Brighton to a height of 603 feet near Long pond, 613 feet near Iliff's pond, 623 feet near Sussex Mills (east of Mulford Station), 639 feet northwest of Woodruff's gap, 640 feet at White lake, and 660 feet at the outer border of the moraine. At lake Grinnell the rise is very regular and uninterrupted. It must be remembered, however, that the line in the profile does not represent the actual surface of the terraces. It is the aggradation level represented by combining the maximum elevations of the terraces.

The moraine at lake Grinnell marks a well-defined pause in the ice retreat. While the active ice edge stopped at this point, the gravel deposits as far southwest as Brighton were formed. Large ice blocks lay in the center of the valley, and the waters deposited sand and gravel around them. The sites of the largest of these blocks are now marked by the row of ponds and marshes from Andover Junction to the moraine. Long pond is reported to have a depth of over 100 feet.

For a mile above the moraine, kames and kame terraces border the stream. They are of massive size, but their heights, 643 to 620 feet, do not permit them to be correlated with the deposits south of the moraine. They may be contemporaneous with the moraine, but more probably were formed a little later, after a slight retreat of the ice edge.

Types of topography.—Broad plains, formed in standing water, are represented by the Quaker Settlement plain. Terrace plains, slightly pitted by kettles, but, in general, formed quite independently of ice action, are present along the Pequest, and along the railway southwest of Huntsville. The greater part of Germany Flats shows the same type of topography, but here the plain is interrupted by extensive ponds and swamps. In many cases the minor features of stagnant ice topography are well shown on the sides of the kettles. They may be seen along the Lehigh and Hudson River railway.

More strongly-marked kame terrace forms, comprising kettles, winding ridges, and narrow terraces bordering the rock hills, are well developed east of Huntsville and Brighton, around White's pond, Hewitt's pond and Long pond.

Near Brighton there are good examples of bare rock ledges at levels lower than the gravel deposits, and in localities such that erosion cannot be supposed to have removed a gravel covering. They must have been covered by the ice when the gravel terraces were deposited.

Discordance between glacial drainage and present streams.—The glacial streams flowed southwest, as is shown by the slope of the terraces. In some localities the present streams flow in directions opposed to this slope. This is shown on the profile. The southwestern extension of Germany Flats is drained by a branch of the Pequest (*h i*) whose headwaters are just above Iliff's pond. The main part of the flats is drained by two streams (*j* and *k*), one flowing northeast, the other southwest. They unite at Sparta Junction and leave this valley by a cross-valley to the northwest. The upper part of the Flats drains into the Wallkill in a direction (*l m*) contrary to the slope of the terraces. These streams were located not by the general slope of the terraces, but by the slopes of the lowest passages along the valley in the upper part of the Flats. This was contrary to the slope of the upper surface of the terraces.

The second main glacial drainage line via Johnsonburg, Hunt's Mills and Newton.—South of Johnsonburg, the stratified drift forms a broad plain, having an elevation at its lower limit of about 550 feet, but rising northward to 580 in the vicinity of Johnsonburg. The aggradation level rises northeastward along Bear creek, reaching a height of about 632 feet in the vicinity of Hunt's Mills. Still further northeast, near the swamp, it attains an elevation of 639 feet. For some distance along this large swamp gravels are absent, but near its northern end they occur, and reach an elevation a little less than 640 feet. So far as could be determined by the map they are slightly lower than those further southwest. At least they do not reach the height to which the natural increase of slope would carry them. The gravels from near Hunt's Mills to a point below Johnsonburg may correspond in time of deposition to the gravels southwest of Brighton, while the gravels northeast of the swamp, extending to Newton, with an aggradation level between 620 and 640 feet, may correspond to the second stage of deposition in the other valley, viz., that from Brighton to the moraine. Data are hardly definite enough to warrant positive assertion.

Types of topography in the preceding belt.—South of Johnsonburg, the stratified deposits form a gently-undulating plain, whose even surface is but slightly interrupted by shallow depressions and low knolls. Much of the same topography is shown north of Springdale, but here the hollows due to blocks of ice are more pronounced. Near Hunt's Mills (Washington), the gravel area is surrounded by

irregular hills of limestone. Its continuity is interrupted by knolls or rock-islands in the gravel plain, and by humus-filled hollows. The general topography is due to a combination of stagnant ice forms and limestone knolls. From the northern end of Bear swamp to Newton, via Muckshaw pond, a distance of over three miles, various types of stagnant ice forms occur. Large kettles and flat-topped kames are common. Over much of this area, also, limestone bosses and hills project through the gravel plain.

Just south of Newton, in the outskirts of the village, the topography of the stratified drift is extremely kame-like. Hillocks and hummocks having a relief of twenty-five feet follow one another in quick succession, with but little regard for a common aggradation level. Ever and anon, however, the aggradation level appears in the form of a well-defined, even if narrow terrace. This is shown in the vicinity of Drake's pond, southeast of Newton. The pond itself occupies a large kettle, which is apparently the site of an ice block. The minor inequalities in the outline of the ice are well marked in reverse by the knolls and depressions on the sides of this large kettle

Stagnant ice forms are also well shown along the narrow belt of gravel between Drake's pond and Stickle pond. The characteristic narrow terraces, flat-topped mounds, and ridges, are also well shown around Muckshaw pond.

Constitution of the gravel.—The bulk of the gravel in the Pequest system is composed of shale, sandstone and greywacke (Hudson River). Limestone pebbles and cobbles are abundant in some exposures, but their abundance is variable. The larger cobbles are commonly of Oneida and Medina. A few gneiss pebbles occur. The gravel is generally well rounded and water-worn; but striated cobbles occur, though not in great numbers. Occasional masses of till are included in the gravel, but such occurrences are rare. In size, the material varies from fine sand to coarse gravel or cobbles. Layers of the finest sand are often interstratified with coarse gravel. Where stagnant ice forms are best developed, the gravel is apt to be coarser than where they are absent. Oxidation has penetrated to depths of three or four feet. Over much of the area the surface is clayey. The greatest known thickness of the gravel is forty-five feet, at which depth its bottom was not reached.

In the Wallkill valley.—The Wallkill heads in a swamp southwest

of Sparta. From this point north to the State line, the stream is bordered interruptedly by considerable deposits of stratified drift, which assume now the form of kames, now of kame terraces, and now of less readily-classifiable forms. On the whole, stratified drift is less abundant along this valley than along any other equally large drainage line in the northwestern part of the State.

At Sparta, near the head of the valley, occur large, massive kames, which rise 60 to 110 feet above the kill. Much of the material of this kame area is very coarse; bowlders up to five or six feet in diameter occur; much of the material is unworn, and still retains striæ. There are no traces of an aggradation level. These facts indicate conditions of deposition somewhat different from those attending the formation of kame terraces. They were doubtless formed when the ice stood in the immediate vicinity. Above Sparta, and from that point to Ogdensburg, the Wallkill has a winding course through a swamp. Locally the lowland has a width of half a mile or more. Through this part of its course the river has done no cutting in post-glacial time, but has devoted itself to the silting up of the wide valley or depression which was left when the ice receded.

At Ogdensburg a triangular embankment of stratified drift extends nearly across the valley from the eastern bluff. This gravel ridge was referred to in the Geology of New Jersey, 1868, and again in the annual report of the State Geologist for 1878. It was described at some length in 1880.* Professor Cook wrote of it as follows: "It is a conspicuous feature of the landscape and affords beautiful views of the valley, both north and south, and it serves as an embankment for the New Jersey Midland railroad (New York, Susquehanna and Western) crossing the valley of the Wallkill. Its (average) height is 660 feet above the sea and 100 feet above the mud level along the kill. The village of Ogdensburg stands partly on its eastern end. Its length, measured on a straight line directly across the valley, is three-quarters of a mile."

At its eastern end where it joins the bluff the embankment has a width of nearly three-quarters of a mile. It narrows steadily to the west and at its western extremity, near the kill, its width along its crest is only two or three hundred yards. Its shape is, therefore, nearly triangular, and the apex of the triangle is so near the western side of the valley as to leave but a narrow passage for the Wallkill.

*Annual Report of the State Geologist, page 51.

If the embankment once extended across the valley so that its western end reached the western bluff, it must have constituted a dam, and have given rise to a lake occupying the flat to the south between Ogdensburg and Sparta. An examination of the gap between the west end of the drift embankment and the bluff to the west, does not make it altogether clear how much, if any, of the present gap is the result of post-glacial erosion. The difficulty of determination is enhanced by the fact that there has been much filling at this point by human agency, especially in connection with the construction of the railway. Such data as are available seem to indicate that the maximum amount of cutting which has occurred in post-glacial time is probably not more than twenty feet. It can be stated with some degree of confidence that the embankment did not extend across the valley at its maximum height. Any water which may have been held back temporarily in the area south of Ogdensburg cannot have had great depth.

The top of the embankment slopes gently westward. In places it is somewhat undulatory, and semi-kame-like in topography. Its steep north and south slopes are marked by shallow depressions and low swells, which give a clue to its origin. Slopes with such topography, and in such relations, could only be found where the gravel was deposited against an irregular surface of ice. This embankment is believed to have been formed in a wide crevasse in the ice body which occupied the valley at this point, while the stratified drift was being laid down. Such a crevasse would be likely to be wider near the side of the valley where the gravel entered, than toward the center. The ice walls between which this deposit of gravel is believed to have been made, could have had little or no motion; otherwise the regularity of the deposit would have been destroyed.

The gravel of the ridge is coarse, although much fine sand is present. Bowlders, even large ones, are occasional. Many of them are striated. As shown by various exposures in the ridge, thick beds of conglomerate have been formed by the cementation of the gravel by lime carbonate.

Following down the valley, there is little stratified drift from Ogdensburg to Franklin Furnace. North of Franklin Furnace there is no continuous body of stratified drift immediately adjacent to the kill for some distance. There are some small areas of stratified drift between Franklin Furnace and Hardistonville, a little out of

the valley. Some of these have forms which suggest that they are delta deposits made in local lakes or ponds. If such bodies of water existed, they must have been held in on one or more sides by the ice.

An interesting deposit of gravel of considerable extent occurs in the vicinity of North Church, reaching eastward essentially to the Wallkill. The stratified drift is here composed of sand and gravel, and constitutes a flat-topped plateau which extends as far west as the old North Church. It is believed to be a delta, and may be called the North Church delta plain (see profile, Figure 3, Plate I.) This plain is a striking feature in the landscape. Its greatest width from east to west is a little more than a mile and three-quarters. Its greatest length from north to south is five-eighths of a mile. The top of the plain is generally flat, but it is occasionally broken by a few broad, shallow depressions. On the whole its upper surface slopes very gently from north to south.

Along its southern and eastern margins, its outline is lobate. Typical delta fronts, with steep slopes and well-marked lobes, are finely developed. Their heights vary considerably. Near the North Church school-house, where the plain fronts the swamp, the abrupt slope is nearly 100 feet high. Eastward the height diminishes rapidly as the surface in front of the plain rises, until at a point north of Franklin Junction, the front slope is not more than twenty feet in height. But the front is here just as clearly a constructional slope built into standing water, as is the higher front farther west. The lobes are clearly outlined, and the re-entrant angles are deep and narrow. While the height of the fronts increases farther east and north-east, it nowhere becomes so high as near the North Church school-house. The height of the front, at different points, was determined by the depth of water into which the delta was built, and this varied. With one exception kames and kettles do not exist along the front of the delta on its south and east sides. Near the school-house, however, there are a few small hillocks on the side of one of the re-entrant angles.

The northern slope of the plain is very different from the southern. Here the plain suddenly breaks up into a succession of massive hillocks and deep kettles at a level considerably lower than the top of the plain. Some of the kettles are as much as 80 feet deep. Nowhere else in Sussex county are the kanes developed on a more massive scale.

Unfortunately much of the area is covered with timber, and therefore a good view of the whole assemblage of hills and hollows is impossible. Bowlders and large cobbles are much more abundant on the kames than on the surface of the plain itself. Nothing can be more clear than that the conditions which prevailed on the northern flank of the plain during its construction were totally unlike those which controlled the development of its southern slopes. Just as the regular slopes and lobate margins on the south tell of the advance of the delta into a lake, and of deposition unhindered by ice, so the knolls, ridges and kettles of the northern slope indicate deposition against ice of very irregular outline. There can be little doubt that the margin of the ice stood where the kames now are when the delta plain was formed.

While exposures are for the most part wanting, so that the structure of this plain cannot be made out, all available data seem to point to the conclusion that it is really a glacial delta, built in a temporary lake, whose surface had an altitude of 620 to 630 feet.

Kames have a strong development a little farther down the valley to the north. The kames become exceptionally abundant and most pronounced just southwest of the Hamburgh station of the Lehigh and Hudson River railroad. Just here is a small but marvellously complex area of hillocks and kettles. This particular spot affords an exhibition of the most pronounced kame topography in New Jersey. The kettles are nearly circular, and their rims are practically unbroken. The hillocks are equally perfect in their dome-shaped outlines. The vertical relief within a few rods is often as much as forty feet. Measured from the top of the largest kame to the bottom of the nearest kettle, the relief must be as much as 80 to 100 feet. This kame area is continued northeastward across the river into the southern part of Hamburgh. It extends a mile farther down the valley toward McAfee, and is more or less continuous with deposits found all along the valley from McAfee to the State line.

Returning now to the North Church area, a narrow belt of kames stretches thence northward to Deckertown (*n o*, Figure 3, Plate I.) This belt of kames does not lie in the valley of the Wallkill, but is closely associated with it. This belt can hardly be called a kame terrace, for no terrace level can be made out, though the kames often reach essentially the same level. On the whole, they rise to the north. Now and then kames are so connected as to suggest an

esker, but no well-formed esker is developed. The kame topography is often strongly marked, there being sometimes a relief of as much as eighty feet within short distances. The gravel sometimes lies against the hills, but more commonly is separated from them by a narrow depression. The position of the kame belt, with regard to the sand plain at North Church, indicates that the kame belt was built along the course of the stream, which, at its mouth, formed the delta plain. The formation of the two may have been contemporaneous, but more probably the plain was constructed first and the kame belt to the north later, as the ice receded.

This kame belt affords the best opportunity known in Sussex county for studying the effect of a change in the surrounding rock upon the constitution of the gravel. The kame belt is bordered on the east by limestone hills which are nearly free from drift. Limestone also borders the kame belt on the west, save for a mile near the north end. The contact between the shale and the limestone crosses the kame belt obliquely near the Papakating cemetery. The northern extension of the gravel area to Van Syckles is through an area of shale.

Exposures at intervals of a mile give opportunity for noting the change in the constitution of the gravel. These exposures show that the underlying formation makes itself felt promptly in the stratified drift, and that the shale becomes less and less abundant after the depositing waters crossed the junction of the shale and the limestone, flowing out upon the latter. The change is more notable in the coarse than in the fine part of the gravel.

Near Deckertown there is another gravel and sand plain, lying a little east of the village, which appears to be similar in many respects to that at North Church. Its greatest diameter is about one mile. Its average elevation is about 100 feet below that of the North Church plain, and at about the same elevation as the kame terraces southeast of Woodbourne, two miles further east. The plain rises from the lowland in front of it by a very steep slope 80 to 100 feet in height. Its southern margin is lobate, and the lobes resemble delta fronts. The characteristic outlines of stagnant ice topography are not present, but in two places the lobes of the plain appear to have been built out so as to reach and partly bury kames which were earlier formed. The delta form is not so distinctly marked on the summit. Instead of being flat or gently sloping, it is pitted by sinks and kettles twenty-

five feet to forty feet deep. One knoll rises ten feet above the general level. Inequalities are less strongly developed near the front of the plain than a little distance back from the edge. The northern and northeastern, or inner slope of the plain, is strongly kame-like. In this respect also it is like the North Church plain.

Northeast of Deckertown there is a long, narrow belt of kames (*p q*, Figure 3, Plate I.) standing in much the same relationship to the Deckertown plain that the Deckertown-Hamburgh belt does to the North Church plain. This kame belt is separated from the northeastern end of the plain by a broad alluvial flat. Frequently an aggradation level is suggested, the highest knolls reaching a common level. Its general gradient is about sixteen feet per mile, sloping to the southward; that is, sloping in a direction contrary to the present course of drainage. The sand and gravel are sometimes distinctly separated from the shale knolls on either hand, though they sometimes rest against the rock hills. The long, narrow form of this belt of stratified drift suggests an esker, but the definitive topography is wanting. The belt is composed rather of a succession of rounded or slightly elongate and somewhat isolated hills of gravel and sand arranged lineally.

A mile south of Quarryville, on the east side of the brook, there is an embankment of gravel jutting out from the hillside into the valley, after the manner of the Ogdensburg embankment, though on a much smaller scale. This also probably represents a crevasse-filling in the ice.

On the east side of the Wallkill, above Hamburgh, gravel has little development for some distance. It is often absent altogether. Due east of Deckertown, and half to three-quarters of a mile north of Independence Corner, there is another huge, spur-like embankment of sand and gravel projecting out into the Wallkill valley from the hillside on the east. The main part of the embankment is triangular, the base of the triangle being against the east bluff of the valley, while the apex is half a mile to the northwest. The embankment closely simulates that at Ogdensburg, and is believed to have had a similar origin.

On the west side of the Wallkill, from Vernon to Glenwood, there are isolated kames, often separated from the valley bottom by hills thinly covered with till. The relation is such as to indicate that ice occupied the center of the valley, which is now covered by alluvial

deposits, and at the same time the lower slopes of the hills up to the bottom of the present gravel deposits, while the latter were making.

In the Vernon valley.—Stratified drift deposits occur interruptedly from Hamburgh to the State line in the Vernon valley. From Hamburgh to Rudeville the stratified drift takes the form of kames, or sometimes of kame terraces. At McAfee, there is a fine development of the kame topography. Kettles twenty to thirty feet deep are closely associated with hills of corresponding dimensions. A good view of this kame and stagnant ice topography can be obtained from the hill opposite the hotel at McAfee.

From McAfee to Sand Hills the kame and kame terrace topography is continuously developed. The name—Sand Hills—is derived from the huge hills of stratified drift in the immediate vicinity. A group of the hills near the station rises 150 feet above the level plain, and the kame terrace to the north is even higher.

The stratified drift in this region frequently attains a considerable thickness, being in some places more than 100 feet. Where it extends around limestone hills, great variations occur within narrow limits, so that its thickness is exceedingly irregular.

A comparison of the heights of the aggradation levels in various parts of the valley shows a southward slope of about ten feet per mile. This is true for that part of the gravel area from the Sprague schoolhouse, southwestward to within half a mile of McAfee, where the aggradation level is better developed than at many other points.

In this valley, as in other valleys of Sussex county, the stratified drift deposits do not hold, throughout the valley, a continuous aggradation level. A distinct grade can be made out for a certain section of the valley, but the grade level for one section seems to be largely or altogether independent of the grade for the sections above and below. The lack of correspondence in the level between the gravels about Sand Hills and those south of McAfee, seem to point clearly to a different time of origin. The 600 to 620-foot plain three-quarters of a mile south of McAfee, was probably formed earlier than the terrace farther north, and before the ice had freed the northern part of the valley. The great mass of kames at McAfee (560 feet) cannot be connected with the aggradation level of the area farther north, nor does it agree with the well-marked levels at any point farther south. The general rule seems to be that the gravels in a certain section of

the valley were deposited while the ice edge stood in a given position. The ice then retreated farther north, and the section freed by the retreat had gravels deposited in it. In the second section, aggradation sometimes built up the valley gravels to the height of those in the section below, and sometimes not. Still farther retreat of the ice freed a third section of the valley, in which deposits were made. These deposits in turn may have failed to reach the levels of those made in other sections at earlier times.

In this valley, as in several others in northern New Jersey, the aggradation level slopes to the southward, while the present drainage is in the opposite direction. Northward-flowing drainage was established when the ice finally disappeared from the valleys.

From Sand Hills north to the State line there is relatively little gravel. At some points, as near Maple Grange, the gravel is confined to the slopes well above the valley bottom, while at the base of the slope below the gravel till appears, as shown in Figure 1. This would seem to indicate clearly that the area where till now occurs was covered by ice when the gravel was deposited.

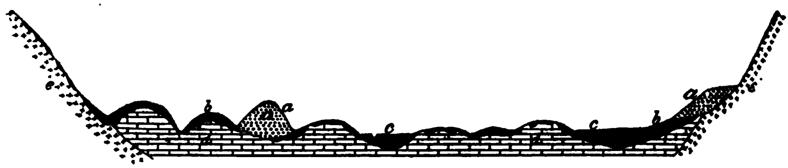

Fig. 1.

Profile illustrating the cross-section of Vernon valley, near Maple Grange: *a a*, gravel and sand; *b b*, till; *c c*, alluvium and peat (depths perhaps too great); *d d*, limestone; *e e*, crystalline schist. Horizontal scale, 1⅓ inches per mile; vertical scale, about five times as great as the horizontal.

In the Musconetcong valley.—The gravel below the moraine in this valley was referred to in an earlier report.* Above the moraine, the stratified drift is abundant as far as Stanhope. In some places it takes on the form of kames. In others its disposition is more regular, though a kame-like habit is somewhat persistent.

Gravel also occurs interruptedly along the valley of Lubber's run, a tributary to the Musconetcong, which joins the latter two miles

*Report for 1892, page 125.

below Stanhope. In this valley the stratified drift is far from continuous. Above Roseville it has the irregular form which tells of deposition against ice. Stratified drift also exists along the valley of the tributary to Lubber's run, coming down from Wright's pond and beyond.

In the Pequannock-Rockaway valley.—In the Pequannock valley, stratified drift deposits are well developed from Newfoundland to Mooseback pond. The stratified drift of this part of the Pequannock valley is continuous with the narrow belt of stratified drift which stretches down the Rockaway to the moraine at Port Oram. This belt of stratified drift is one in origin, although it is now drained by streams flowing in opposite directions.

From Newfoundland to Oak Ridge, the stratified drift is disposed principally in the form of kames. This is especially true north of the railway. The topography of the kame area is rough, having a relief of twenty to thirty feet. It consists of ridges and hills composed of coarse gravel and occasional bowlders, alternating with basins, and trough-like depressions. South of the river in the same part of its course, the stratified drift assumes rather the form of a terrace sloping to the southward, but its surface is interrupted to some extent by depressions, some of which are occupied by swamps. Continuing southward, this belt of stratified drift becomes somewhat complicated, and difficult of classification, in the vicinity of Petersburg. From this point south, the stratified drift is almost continuous down the Rockaway to the moraine. It has a general southward gradient amounting to 140 or 150 feet from the vicinity of Newfoundland to the moraine, a distance of twelve miles.

Within this belt, kames are well shown north and east of Mooseback pond, at Upper Longwood, at Lower Longwood and at Berkshire valley. The stagnant ice forms have good development south of Oak Ridge station, and for a short distance east, south of Mooseback pond, and at Berkshire valley. The terrace form is best seen at a point three-quarters of a mile west of Milton, on the south side of the railway, and from Milton to Woodstock, along the west side of the valley.

Isolated patches of stratified drift.—Apart from the stratified drift which occurs along the valleys, there are here and there patches of stratified drift of greater or less extent, which are more or less

isolated. Some of these occur on uplands, while others are at low altitudes.

There is a little stratified drift in many of the small valleys tributary to the larger ones which have been described. This is true both of the great Kittatinny valley, and of the highland area to the east, as far as the Green Pond mountain range. In these minor valleys, the stratified drift has the same general character, both as to constitution and disposition, as in the larger ones. The greatest body of such drift which has not been separately mentioned is found west of Bear Fort mountain, and a short distance east of Carey's mine. It has an interrupted linear extent of more than three miles. Its topography is kame-like, with a relief of ten to twenty feet. Its disposition indicates that it was deposited against ice which must have been stagnant or nearly so.

There is also a greater or less amount of stratified drift about many of the ponds and lakes. The patches of stratified drift about the lakes are often more or less kame-like, and sometimes assume the forms of kame terraces. This is true about Sucker pond, and for about three miles northeast of the same. It is also true about Swartswood lake and Catfish pond, and about several of the lakes between the east line of Sussex county and Green Pond mountain.

There are stratified drift deposits of the overwash plain type, adjacent to the recessional moraine which has an interrupted existence from Long pond to Ogdensburg. Along this moraine, gravel of the overwash plain type may be seen a little west of Balesville; also at Washingtonville, and near Branchville Junction. Inside the recessional moraine there is also stratified drift to a considerable extent at various points. This is especially true north of Balesville and at a few other points.

There are a considerable number of kames about Andover. Over most of the area in the vicinity where the kames occur, there is no trace of an aggradation level, and the topography is much more that of a kame area than that of a kame terrace. In and about Andover Junction, however, there is an approach to a kame terrace topography, where the aggradation level appears to be 650 feet.

There are small bodies of stratified drift on high levels not associated with valleys. Thus at Culver's gap, on Kittatinny mountain, there is a kame-like accumulation of stratified drift. Small bodies of stratified drift also occur a mile or so northwest of the gap. Isolated

patches of small extent are known at a few other points on the range. It is quite possible that there may be small patches of stratified drift or kames at other points not known. The mountain is so generally covered by forests, and is crossed so infrequently by roads or paths, that small areas of sand or gravel may have escaped observation.

On Pochuck mountain there are some kames which occupy a sort of amphitheater two and one-quarter miles northeast of Hamburgh, and a mile and a quarter east of south of Independence Corner. From the kames at this point, a splendid view can be obtained of the crest of the Kittatinny mountain, and the broad, rolling Kittatinny valley. There are many other places on the highland area between Green Pond mountain and the Kittatinny valley, where isolated bodies of stratified drift occur. These are usually of small extent and present no unusual features, and do not call for individual mention here.

ESKERS.

Eskers are exceedingly rare in the northwestern part of the State; even those which exist are ill-developed. In Warren county there are two, and in Sussex county there are three ridges of drift which may be classed in the category of eskers. One of the eskers in Warren county lies on the northern slope of the limestone hill, nearly three-quarters of a mile northeast of Walnut Valley. Its length is not more than 250 yards, and its width 50 to 60. At its upper end it thins out gradually; at its lower, it ends abruptly. Its crest is undulatory, and nowhere does it rise to a great height above its surroundings. It is not so distinct but that question might be raised as to the propriety of calling it an esker.

The other esker-like ridge in Warren county is north of Southtown, southwest of Glover's pond. Its length is 350 to 400 yards, and its width 40 to 50 yards. Its height is five to fifteen feet above its surroundings. At its northern end it terminates sharply at the swamp, while southward it fades away on the hillside.

Of the three eskers found in Sussex county, the best developed is in the midst of the kame area southwest of Unionville (N. Y.). It begins about a mile southwest of Unionville, a little south of the road which runs from Unionville to Clove brook. At its northern end, it is not distinctly separable from the kame deposits about it, but southward it becomes sharply ridge-like in form, and is bordered on

either side by a swamp, above which it rises steeply for twenty feet. It is somewhat sinuous, has a narrow top and steep slopes. After a course of 450 yards, it ends abruptly at the swamp, but after a break of fifty yards it begins again as a low, winding ridge, not more than five feet above the swamp. Its height soon increases to twenty feet. It is again interrupted by the swamp for about 300 yards, but is continued again in the kame area on the south. Here it is a sharply-marked, slightly-sinuous ridge, with steep sides and narrow top, with undulating crest. At its southern end, it merges again into kame deposits.

Another small esker occurs east of Hainesville, near Averytown. This is a narrow, sharply-defined, curving ridge, having a height of from fifteen to eighteen feet through a part of its course. It is well defined throughout its entire length. Its crest is narrow and its slopes steep. It is twice broken by brooks which cross it. Including these gaps, its length is about 500 yards.

The third body of drift which approaches an esker in form is midway between Glenwood and De Kays. It is a long belt of gravel, the length of which in New Jersey is about three-quarters of a mile. It is ill-formed and is made up of a succession of elongate knolls rather than of a distinct ridge. It is doubtful whether it should be classed as an esker.

B. DRIFT ON THE BEAR FORT, KANOUSE, GREEN POND AND COPPERAS MOUNTAINS.*

This series of mountains may be considered as one in this connection. Together they constitute a sort of dividing ridge between the eastern and western parts of the State, a division which has some significance from the standpoint of our present study. On the whole, these mountains are but thinly covered with the deposits of the glacial period.

I. TILL.

On Bear Fort mountain.—The most conspicuous feature of the glacial geology of this mountain is its paucity of drift. Outcrops of

*The following statements concerning the drift of these mountains, as well as the area farther east, are based largely on the detailed work of Charles E. Peet.

rock occur by the hundred, perhaps by the thousand. It is probable that the aggregate area which is essentially free from drift, equals the aggregate area where the rock is concealed. Drift seems to be least abundant over the central part of the range. Till is more abundant on the west slope than on the crest and east slope. For the whole mountain, the average thickness of till can hardly be more than five to ten feet.

Such till as is present is bowldery, and the local rock greatly predominates. Gneiss and crystalline schist bowlders are occasionally found over the whole mountain, and locally they are abundant. Locally, also, much shale enters into the composition of the drift. This is especially true near the outcrops of this formation.

The surface of the exposed rock on Bear Fort mountain is much weathered, and striæ are rarely preserved, if they were ever abundantly developed, as seems doubtful. In the valley east of Bear Fort mountain, outcrops of rock are frequent. The till which occurs here is made up principally of the slate, or sandstone, derived from the local formation.

On Kanouse mountain.—Kanouse mountain has more drift upon its surface than Bear Fort. Though the drift is thin, the total area where the rock is concealed, is far greater than that where it is exposed.

The till is predominantly of material derived from the mountain itself, but there is a not inconsiderable amount of gneiss and schist derived from the region to the northeast.

On Green Pond and Copperas mountains.—The west faces of these mountains are very generally till-covered. This is especially true where the slopes are gentle. Outcrops of rock occur at Woodstock, and between Upper and Lower Longwood. They are abundant between the latter place and Berkshire Valley.

The steep east face of the mountain is generally free, or essentially free from drift. Quantities of talus have accumulated at the base of the vertical ledges. The crests, both of Green Pond and Copperas mountains, have little drift, rock outcropping frequently.

While the till of these mountains is essentially local, there is more or less schist, gneiss and shale commingled with material which is strictly local.

II. STRATIFIED DRIFT.

The stratified drift associated with the Bear Fort-Kanouse-Green Pond-Copperas mountain belt is chiefly confined to the valleys between Kanouse and Bear Fort mountains, and between Green Pond and Copperas. It therefore lies mainly on the shale or slate.

There are four principal areas of the stratified drift—1°, at the south end of Greenwood lake; 2°, north of Postville; 3°, east and south of Newfoundland, and 4°, at the ends of Green pond.

In the first of these localities the stratified drift occupies two levels more or less separated from each other. The upper series of gravel deposits occur at about 740 feet, and seem to have been laid down against ice after it had lost its motion, or at least to have still rested against it after it lost its motion, since some of them have the form of a kame terrace. This is especially true on the west side of the valley, where the terrace slopes eastward, becoming undulatory and kame-like toward the axis of the valley.

In the second of the localities mentioned above, the stratified drift consists of a small area of kames, one and one-quarter miles north of Postville. South of the kames there stretches a plain of stratified drift, the surface of which is somewhat pitted. It declines from 837 feet to 800 feet in one and one-quarter miles, the material becoming finer and finer as the surface lowers. The ice edge is believed to have stood at the kame area, while drainage from it developed the pitted plain to the south. North of the kames there are some gravel ridges, one of which has something of an esker-like form.

At the third locality, east of Newfoundland, there are some well-developed kames. They lie one-half mile east of the depot. They are part and parcel of the stratified drift of the Pequannock valley already described. These kames are probably contemporaneous with those of Oak Ridge.

The stratified drift at the north end of Green pond is much more extensive than that at the south. It has the form of a very gently-undulatory plain sloping southward, the material becoming finer as the surface declines. Well data show that the depth of the drift at the north end of the lake is more than fifty-five feet, although the pond now drains to the south. Data are at hand to show that if the drift were removed from the valley, it would be deeper north of

the pond than south of it, and that the valley, the damming of which has given origin to the lake, was doubtless a tributary to the Pequannock in pre-glacial times.

C. DRIFT EAST OF THE GREEN POND MOUNTAIN RANGE.

I. UNSTRATIFIED DRIFT. TILL.

On the crystalline highlands.—In this area, the drift does not greatly mask the pre-glacial surface. The main topographic features are due to the rock, not to the drift. Till overspreads almost the whole of the region, though its continuity is frequently interrupted by the projection of points and ledges of bare rock. The till is of the type which is appropriate to the region, considering the nature of the underlying formation. It is made up of just such material as would result from the comminution of the crystalline schists themselves. Its numerous stones and bowlders were derived principally from the gneiss. Other varieties of stony material are present, but are notably less abundant in the eastern part of the area than in the western. This shows that the ice carried less material to the crystalline highlands from the Triassic formation to the east, than from the Paleozoic formations to the northwest.

In the vicinity of the Green Pond mountain range, there is a good deal of stony material which has been derived from that range. This includes sandstone, quartzite and comglomerate. The till is richer in these materials near the mountain than at a distance from it. They are more abundant at a given distance from the south end of the range than at the same distance farther north. Thus in the latitude of Greenwood lake, Green Pond mountain bowlders make up twenty per cent. of the stony material of the drift one mile east of the range, which at the same distance from the southern end of the range, the same mountain has often contributed fifty per cent. of the stony material which enters into the constitution of the till. Small quantities of material from the Green Pond mountain range extend eastward to the limit of the crystalline schist area, and beyond, as will be noted later.

Stony material derived from the Hudson River (?) formation, including sandstone, shale and slate, is of frequent occurrence in this area.

At the south end of Greenwood lake the till is largely made up of material derived from this formation, which outcrops close at hand. Besides the constituents already mentioned, there is an occasional limestone bowlder, and, especially toward the eastern part of the area, an occasional piece of Triassic sandstone.

In general the till has been noticeably weathered and oxidized to an average depth of about two and one-half feet.

The maximum depth of till known in this area is at Bloomingdale, where it has a thickness of sixty feet. The till is thicker along the Pequannock valley than either north or south of it. In the valley, the till is known to be thirty to fifty feet deep at many places. The average depth of till for the whole area probably does not exceed twenty feet. Throughout the area, outcrops are numerous on the tops and steep slopes of the higher hills.

East of the crystalline schist highlands and west of the Palisade ridge.—The topography of the surface in this area is much more largely controlled by drift than in the region just west; but even here the larger features are the result of the underlying rock structures. The stratified drift here occupies about one-fourth as much of the surface as the unstratified. In general the former occupies the lower levels, especially the valleys, while the latter occupies the elevations and some of the low plains which are not along drainage lines. The areal distribution of the till is thus seen to stand in close relationship to the topography. There is also an intimate connection between its thickness and topography. Where the surface is low and approximately flat, the till is likely to be thick. It is also frequently thick between ridges, where till instead of stratified drift is found in such positions. Between Second and Third mountains, south of the Passaic, depths of thirty-five to forty feet are not infrequent. In the trough-like valley between First and Second mountains, the maximum depth is still greater.

In many places the crests of First, Second and Third mountains are nearly free from drift. When present at all, it is often no more than three to five or ten feet deep. The average depth on the crests of these mountains is probably not more than three to five feet. On the slopes, too, especially on the steep eastern slopes, it is relatively thin when not altogether absent. The gentler western slopes are often well covered.

East of First mountain, on the Triassic sandstone and shale, the

average depth of till for the northern part of the area is probably twenty to thirty feet, though depths of seventy and eighty-five feet are known near Norwood and Kinderkamac respectively. In the southern part of the area, the average depth of till is probably a little greater. Here, too, the distribution of the till stands in close relationship to topography. The sandstone ridges extending from Ridgefield Park north to the latitude of Cresskill, and from Harrison to Hackensack and beyond, have relatively thin coatings of till. Rarely does the till dispose itself in the form of drumlins. The accumulations of till, which might pass under this name, have been referred to in an earlier report.*

The constitution of the till.—Within this region three more or less distinct types of till occur, the distinction being based on lithological constitution. These are 1° the gneissic type, 2° the trap type, and 3° the red sandstone type. As these names suggest, the extremely local character of the till is often well shown. The trap type of till is found especially on the trap ridges, though it frequently covers the border of the Triassic formation adjacent on the west. This is consistent with the direction of ice motion, which was rather more to the west of south than the trend of the trap mountains.

The gneissic type of till is confined to the northwestern part of the area, north of a line drawn through Hillsdale, Ridgewood and Pompton. North of this line, the till is seldom red, and the absence of this color indicates the absence or the paucity of the Triassic material. In most places the Triassic material is present, even where the dominant constituent of the till is gneiss. Within the area indicated, seventy to ninety-five per cent. of the bowlders are of gneiss. South of this line the till is much less bowldery than north of it.

South of the area defined above, the red type of till predominates, being derived largely from the Triassic shale and sandstone. The Triassic type of till becomes increasingly clayey to the south, where the formation is more shaley than to the north. In the southern part of the area, especially over the lowlands about Rahway and Elizabeth, the till is often very clayey, and has an unusually level surface. Its character and its disposition are such as to have raised the question of the submergence of this region since the ice retreat. It is now thought probable that the region has not been beneath the sea since the last ice epoch, but that it stood so low during the melting of the ice

*Annual Report of the State Geologist for 1891, page 74.

that the water failed to flow readily from it. To this semi-submergence under ice-water, some of the peculiarities of the till are tentatively attributed. Within the basin of Lake Passaic the till has certain peculiar characteristics, which have been noted elsewhere.*

In addition to the material derived from the three formations specified, there are some bowlders from the Green Pond mountain range, from the Hudson River (?) sandstone, and occasionally from some formation of limestone which lies north of the State line. Their source may be the Triassic conglomerate which locally is composed largely of limestone.

The Hudson River (?) constituent of the till occurs much more abundantly in the northern part of the area than further south. It is found especially west of Montville. Bowlders derived from this formation were much less well adapted to extensive transportation at the hands of the ice, than those from the Green Pond mountain or gneiss formations. The Green Pond mountain conglomerates and quartzites have not been seen east of the Hackensack valley. West and south of this valley they have a very wide distribution. They are known to occur at Perth Amboy, and even on Staten Island as far east as Annadale. Bowlders of gneiss or crystalline schist are not restricted to the area where the gneissic type of till prevails. They occur in all parts of the area, and even beyond it, on the Palisade ridge.

It is to be noticed that the strike of the formations in this region is northeast and southwest. The line of contact between the Triassic formation and the crystalline highlands to the west has a direction 45° to 50° west of south. Striæ in this region show that the direction of ice movement was S. 10° to 20° W. This direction of movement would carry materials from the more westerly formations over to the more easterly, but not materials from the more easterly formations to the more westerly. The only place where this could take place is along certain parts of the trap ridges, where their direction departs from the normal direction of strike of the formations in this part of the State.

It is to be noticed that there are certain anomalous things in the distribution of the materials. The easternmost point where Green Pond mountain bowlders have been seen (on Staten Island) is several degrees east of south of the easternmost point of the Green Pond mountain formation in New Jersey. Throughout the whole of the

*Annual Report of the State Geologist for 1893, page 294.

intervening area where striæ have been recorded, the direction of ice movement was west of south. It is therefore certain that the Green Pond mountain bowlders found on Staten Island, and in Union and Middlesex counties, did not come from the Green Pond mountain range of New Jersey during the last ice epoch. The Green Pond mountain formation is continued northward into New York, and its northward continuation is farther east than the range in New Jersey. It is possible that the bowlders of this formation found in the eastern part of the area under consideration, came from this northward extension of the formation. This explanation does not seem to be free from difficulties, since the bowlders increase somewhat regularly in abundance as the Green Pond mountain range within the State is approached. There would seem to be no good reason for this especial feature of their distribution, if the bowlders at the southern limit of the ice had been derived from the New York continuation of the formation.

The other alternative is to suppose that glacier ice affected this part of the State during at least two distinctly different epochs, and that during the first the movement was more to the east than during the second. During the first, the bowlders might have been carried from the Green Pond mountain range eastward to the Hackensack valley, and to Perth Amboy and Staten Island. During the next, or any later epoch, the bowlders, if already strewn over the territory east of the mountain range, might have been incorporated in the new sheet of drift.

A study of the distribution of the corresponding bowlders in New York, together with a study of the striæ in that region, would throw much light upon this question. If the northward continuation of the axis of the glacial lobe which lay west of the Palisade ridge be found to cross the Green Pond mountain formation in New York, it might be possible to explain the present distribution of the Green Pond mountain bowlders, on the supposition that there was but a single ice epoch. Otherwise the other interpretation would seem to be necessary.

Oxidation and weathering.—The surface of the till in this region does not usually afford direct testimony as to the amount of oxidation and surface change which have taken place since its deposition. The prevalent color of the till is such that oxidation does not notably affect it. Where the till is of the trap and gneiss types, oxidation is more readily seen. The depth to which it has extended corresponds

in a general way to the depth to which it has affected the till farther west, viz., two or three feet.

Till on the Palisade ridge.—The till on the Palisade ridge was considered in some detail in the Annual Report of 1893.* The striæ on the Palisade ridge point east of south. This direction of ice movement, taken in connection with the direction of movement west of the ridge, makes it clear that the axis of an ice lobe occupied approximately the position of the Hackensack valley and its southerly continuation. West of the axis the movement was to the west; east of it, the movement was to the east. As would be expected under such circumstances, the material from the Triassic formation was carried up on the trap ridge to some extent. The Triassic material even predominates on the west face of the Palisade ridge for some distance above the junction of the two formations. While the predominant materials of the till on the trap ridge are always trap and Triassic sandstone, bowlders of gneiss and crystalline schist are by no means rare. Some of them are of great size. There is nothing in the character of these bowlders to indicate that they were not derived from the crystalline schist highlands of the State; but considering the direction of striæ on the ridge, it is more likely they came from the northeasterly continuation of these highlands in New York.

II. STRATIFIED DRIFT.

On the crystalline highlands.—The stratified drift on the crystalline highlands east of the Green Pond mountain range occurs mainly in the valleys, along which it is very generally present. Besides its occurrence in the valleys, small bodies of stratified drift occur at many points in the form of kames or of small, unclassifiable patches. None of these minor bodies of stratified drift are of great importance, and nowhere do they assume forms of especial significance.

In the valley of Green Pond brook, there is a narrow belt of gravel along the stream from Middle Forge to the moraine at Spicertown. The gravel slopes gradually to the south, and with the decline the material becomes finer.

Along Beaver brook, gravel is found from Meriden to Rockaway. Its surface declines to the south, though not regularly. The stratified drift of this valley sometimes assumes a more or less kame-like

* Page 177 *et seq.*

topography, suggesting the presence of ice at the time of its deposition. At other points the gravel is disposed as a kame terrace.

In the Rockaway valley, where stratified drift is present, it sometimes has the form of a wide terrace with plane topography, which is now and then broken by deep sinks. From Powerville south, the stratified drift in this valley is remarkable, in that its surface declines to the northeast, according to the topographic map. The glacial drainage was in the opposite direction, so long as ice blocked the Rockaway. It is possible that the present slope was established after this valley was freed from ice. The gravel along the Rockaway north of the moraine is really continuous with the gravel of the overwash plain which extends from the moraine up the valley of Den brook, west of Denville, and also east of Denville, and along the brook toward Tabor. The level of the gravel in these valleys is somewhat higher than that of the Rockaway itself, and was probably laid down somewhat earlier. The abundant gravel deposits along the Rockaway in the vicinity of Boonton, were connected in origin with lake Passaic, and have been described elsewhere.* The other deposits of stratified drift which were connected in origin with lake Passaic have likewise been described † heretofore, and will not receive further mention here.

In the valley of the Pequannock there is a little stratified drift east of Butler. In this direction the stratified drift of the Pequannock becomes continuous with the gravel plain of the Pompton river at Pompton.

In the valley of the Wanaque, stratified drift has a very much more considerable development than in the other valleys in the area under consideration. It is more or less continuous from Hewitt to Pompton. In addition to the gravel along the main stream, there is more or less along its tributaries. This is notably true of the valley of Ringwood creek, and of the creek which drains Sheppard pond. Just below Ringwood, and again in the vicinity of Boardville, the gravel covers very considerable areas. Farther south, in the vicinity of Midvale and Wanaque, the gravel is somewhat extensively developed on the lowlands, both along the immediate course of the stream, and along the belt of lowland followed by the railway.

As in all valleys similarly situated, the stratified drift along the

*Annual Report of the State Geologist of New Jersey, 1893, pages 277-284.

† Loc. cit., pages 277-289.

Wanaque declines to the southward. The rate of decline is greatest just south of Ringwood, being thirty to forty feet for the first mile. Below this point, its decline is about twelve feet per mile. Except locally, its topography is not notably irregular. Topography which is thought to be characteristic of deposits made against stagnant ice occurs at a few points, especially, 1°, near Boardville; 2°, a mile south of that place; 3°, half a mile west of Midvale, and for a mile or so farther south.

The gravel does not decrease in coarseness from north to south with regularity. It is relatively coarse at Ringwood, near Boardville, and again a mile north of Midvale. From all these places its coarseness diminishes southward. In this variation in coarseness is found another indication that the gravel of the valleys was deposited in sections.*

The other areas of stratified drift of the crystalline highland area east of the Green Pond mountain are small, and need not be separately mentioned in this connection.

On the Triassic.—Stratified drift is very much more abundant in this area than in any other part of the glaciated territory of New Jersey. Between the Palisade ridge and a line drawn from Pompton to Newark, the total area of stratified drift is approximately equal to that of till. South and west of the above line, the ratio of stratified drift to till is much less. The stratified drift is found along all the valleys, and occupies much low land which does not border streams. It occurs at higher levels to the north than to the south. Its levels in different valleys are independent of each other, especially to the north, where the several valleys are most distinctly separated. Near the northern line of the State, its altitude is ninety feet in the valley of the Hackensack, 140 feet in the valley of the Pascack, 240 feet in the valley of the Saddle, and 300 feet in the valley of the Ramapo. Traced southward in each of these valleys, the level of the stratified drift reaches the level of the sea about the area at the head of Newark bay. It follows that in its decline to the south, the stratified drift in the various valleys is not regular. In latitude 40° 54′, the upper levels of the valley drift in the above valleys is as follows: In the Hackensack, which has received the Pascack, forty feet; in the Saddle, sixty feet; in the Passaic, which has received the Ramapo, fifty feet.

* See *ante*, pages 45–6.

It is to be noted that there is much stratified drift in this area which cannot be called valley drift. The above figures refer to the latter. The changing gradients of the valley drift are such as to indicate that it was not deposited chiefly after the ice had receded beyond the borders of the State, but in successive sections while the ice was withdrawing. During its withdrawal the ice seems to have halted at various points. Just below the positions of halting, deposition was going on, filling the valleys and covering the adjacent lowlands, establishing there a somewhat definite gradient, or aggradation level. After establishing a definite aggradation level for a certain portion of the valley below its edge, the ice appears to have receded again somewhat promptly for a short distance. In the part of the valley freed from ice by this recession, deposition took place, and a new aggradation level was established for this part of the valley, more or less independent of the one below. Farther recession gave rise to similar filling in a section of the valley still higher up, and so on.

Extra-valley stratified drift occupies the low inter-stream areas more or less generally. It was not deposited by streams after the ice withdrew from these areas, but by water as it issued from the ice, or perhaps even under the edge of the ice as the latter became inactive, or as it approached inactivity. The stratified drift which occupies the inter-stream areas is usually coarser than the valley drift, and occurs at higher levels. It often slopes to the drift in the valleys, so that there is not usually a sharply-marked topographic limit between them.

In some of the valleys there are several places where the edge of the ice seems to have halted in its retreat. These positions are indicated by the behavior of the stratified drift. In some cases the halts in the various valleys may be correlated with each other with some degree of probability, though it is far from certain that the edge of the ice became stationary in all valleys at the same time, even where it became periodically stationary in each.

The first position where the edge of the ice seems to have remained stationary in its retreat from the moraine, is marked by the belt of the moraine-like kames extending from Waverly to Westfield. It is possible that the moraine-like accumulations of drift in Harrison should be connected with this stage, though this is not certain.

A second halting place of the receding ice seems to be indicated by

the semi-moraine-like accumulation of drift which extends interruptedly from North Newark to Cedar Grove. Below this belt, from Riverside to Newark, the stratified drift along the Passaic has an aggradation level independent of that farther up the valley.

In the several valleys of the area there are localities which seem to mark halting places of the ice for the valleys individually. At these various points, the ice front seems to have stood for a sufficiently long time to give rise to some little amount of marginal accumulation, and to interfere with the regularity of the slope of the valley drift. The more marked halting places in the several valleys are as follows:

1°. In the *Passaic* valley, at Delawanna, Garfield and Paterson, and at the head of the tributary valley which comes down from Van Winkle, near Paterson. The gradient of the valley drift below Paterson, seems to be altogether independent of that above. 2°. In the *Ramapo* valley, the ice edge seems to have remained stationary in position for some little time at Oakland, at a point three miles above Oakland, and again three-quarters of a mile south of Darlington. From each of these three positions the surface of the valley drift slopes southward somewhat regularly, after the fashion of a valley train. But each of these positions seems to mark the head of a train independent of the others. A fourth gradient exists above Darlington, the head of which is north of the State line. 3°. In the valley of the *Saddle* river, stationary positions of the ice front are not clearly marked. One is suggested by the kames between Arcola and Rochelle Park. 4°. In the valley of the *Hackensack* the ice edge probably lingered for some time near Hackensack, and again in the latitude of Rivervale. At this point there is a series of kames, from which there extends to the south a well-defined overwash plain of stratified drift, which is independent of the valley drift above the kames. 5°. In the valley of the *Pascack*, above its junction with the Hackensack, a stationary position of the ice edge is indicated by the kames at Montvale. From them a well-marked valley plain, stretching to the south, takes its origin. 6°. In the valley of the *Tienekill*, two temporary halts of the ice edge are indicated, the one at Highwood, and the other at Demarest. At the former place there are two sharply-marked kames, from which a well-defined gravel plain stretches to the south at a level altogether independent of the level of the drift in the valley to the north. The halt at Damarest is believed to be marked by the striking series of kames in that vicinity.

A few words may be added concerning the stratified drift of the several valleys individually.

In the Ramapo valley.—Stratified drift borders this valley on one or both sides most of the way from the State line to Pompton. The width of the belt is usually a quarter to a half mile, rarely more. In some parts of the valley the stratified drift has the form of kames; in others it assumes the form of kame terraces, though never sharply defined, while in still others, it is disposed as a plain. Irregularities in its disposition occur a mile south of the State line, at Darlington, especially west of the river, and at several points between Darlington and Oakland.

The most striking feature in the disposition of the drift of this valley is connected in origin with the halts of the ice already enumerated. The disposition of the gravel in this valley seems to show five more or less well-defined halting places of the ice. 1. The valley plain of gravel extending from the State line to a point near Darlington (*a b*, Figure 4, Plate I.) appears to have been made at one time, after the ice had retreated north of the State line. It has a distinct southward slope from 290 or 300 feet at the State line, to 270 or 280 feet two and one-half miles farther down the stream, near Darlington. 2. Just below Darlington the valley gravel occupies a higher position than to the north—about 300 feet. From this point (*c*) its surface descends to 280 feet in one mile (*d*), though the surface is by no means regular in its decline. 3. Two miles below Darlington the level of the valley drift is again higher than to the north. The rise from the north is accomplished by a steep slope up to a delta-like body of gravel (*e f*) having an elevation of 300 feet. To the south its surface declines to 250 feet within a mile. Just north of this flat-topped, delta-like body of gravel there is a kame at a considerably lower level, showing that the valley just above the plain must have been occupied by ice while the plain was in process of growth. 4. A mile below (two miles above Oakland) the height of the valley gravel again rises in passing southward, attaining a level of about 280 to 290 feet (*h*). This elevation is maintained for a distance of one and one-half miles, nearly to Oakland. Along this stretch the stratified drift has a topography characteristic of material deposited against ice. 5. The level of the gravel in the valley again rises notably at Oakland (*i*), having an elevation of 320 feet in the northwestern part

of the village. South from Oakland the gravel becomes finer and contains a larger percentage of sandy and earthy material.

The constitution of the gravel of the Ramapo valley indicates that even the stratified drift of the valleys is largely influenced by the subjacent terrane. North of Darlington the gravel is principally composed of gneiss. A mile south of Darlington the valley crosses the trap ridge, and trap enters promptly into the composition of the valley drift. Farther southward the gneiss and the trap become less abundant and the Triassic sandstone increases.

The greatest depth of gravel known in this valley is 117 feet.* At Oakland stratified drift is known to have a depth of eighty feet.

Stratified drift between the Ramapo and the Saddle rivers.—East of the Ramapo valley, about Franklin lake, and from that lake to Crystal Lake station, there are considerable and somewhat unusual areas of stratified drift. The gravel area northwest of Franklin lake was probably made when the edge of the ice stood at its northern border. Its surface slopes to the southeast. Its northern and northwestern slopes are steep, and were probably built against, or out from, the ice front. The plain is marked by various depressions which are believed to represent the position of ice blocks when the gravel was being deposited. Franklin lake occupies one of these depressions. From this plain a series of kames extends northward to Crystal lake and beyond, the topography being notably rough at several points.

About Wyckoff there is a large area of kames, having a very rough topography. The swells are often so ridge-like as to suggest eskers, and the depressions are correspondingly elongate. South of the kames proper, a pitted plain stretches to the south for a distance of two and one-half miles. There is also stratified drift to the southeast, along the railway from Wyckoff to Wortendyke, but it has no distinct topographic form. North of Wyckoff there is an abundance of stratified drift for three or four miles along the valley of the creek tributary to the Ramapo at Darlington. This was doubtless deposited before the outlet to the Ramapo was open. The gravel here frequently assumes the form of kames. There is also a small esker associated with the gravel of this area.

In the Mahwah valley.—Kames and eskers, as well as gravel of no distinct topographic form, occur in the valley of the Mahwah, tribu-

*Annual Report of the State Geologist for 1877.

tary to the Ramapo near the State line. The kames are especially well developed in the valley south of Mahwah for a mile and a half. Eskers and esker-like kames occur on the east side of the railroad from the State line to Ramseys. The eskers are on the east side of the valley. They are mainly very short, and their courses are oblique to the slope, their northern ends being higher than the southern; nevertheless, instances are not wanting where the eskers locally ascend (to the south) slopes in some of their windings. Eskers have some development about Ramseys, as will be noted later. There is an undulatory tract of stratified drift at Allendale, and smaller areas at a few points both north and south of that village.

In the Saddle river valley.—Stratified drift occupies the valley of the Saddle river from the State line southward to Garfield. The gravel has an elevation of 240 feet at the State line. Its surface slopes to the south, with a generally diminishing gradient. The following figures express its decline for the intervals noted: For the first mile from the State line, forty feet; for the next two miles, sixty feet (average of thirty feet per mile); for the fourth, twenty feet; for the fifth, ten feet; for the sixth, ten feet; for the seventh, thirty feet; for the eighth, ten feet; for the ninth, ten feet; for the tenth, ten feet. The rapid decline in the seventh mile from the State line doubtless means that the ice edge made a halt just above this high gradient, long enough to establish it.

South of Hohokus, the valley belt of stratified drift widens rapidly, and becomes continuous with the gravel of the Pascack and Hohokus creeks. Still farther to the south and southwest, it becomes continuous with the gravel of the Passaic, although not covering all the surface intervening between these streams. Here and there swells of till rise above the level of the sand and gravel.

In the Passaic valley.—From Paterson east and south, the gravel in the valley of the Passaic has the form of kames, kame terraces, and plains. There are also irregular accumulations which cannot be placed in any one of these categories. As already indicated, several distinct positions of the ice front are indicated by the deposits of this valley between Newark and Paterson. The general southward slope of the valley drift is interrupted at these positions.

In the valley of the Pascack.—Stratified drift is found along this valley continuously from the State line to Hillsdale. Below Hillsdale it spreads out so as to become continuous with the stratified drift

of the Saddle river valley on the west, and with that of the Hackensack on the east.

Between Park Ridge and Montvale, there is a bunch of kames in the valley from which the gravel plain to the south may be said to take its origin. The surface of the stratified drift declines regularly to the south with a continually decreasing slope to Hillsdale and Westwood, the material becoming finer at the same time. The topography of the valley drift is often marked by sinks, less commonly by kame-like elevations. It is more of a plain than most of the gravel along many of the valleys of northern New Jersey. It is probable that stagnant ice occupied the center of this valley much of the way from Park Ridge to Westwood, while stratified drift was being deposited on either hand.

In the Hackensack valley.—Along the valley of the Hackensack, stratified drift occurs more or less continuously from the State line south to the head of Newark bay. The disposition of the sand and gravel in this valley is comparable to that of the valleys already mentioned. It declines to the south, but there are notable irregularities in its slope. It is interrupted here and there by kames which stand somewhat above the general level.

There are a few places where the gravel assumes forms of peculiar significance and interest. Near the Anderson Street station, in Hackensack, there is a flat-topped gravel plain having somewhat the form of a delta. It rises somewhat promptly about twenty feet above the sand plain about it, though the slopes are not normal delta slopes. The north slope of the plain falls off abruptly, especially near the west border. The east slope is gentle. The upper surface of this plain is essentially level. There is much in the topography and surroundings to suggest that it is a delta plain, but it seems to lack the decisive marks.

About a quarter of a mile east of the Little Ferry depot, there is what appears to be a low spit starting at a height of twenty feet, and sloping southward.

In the vicinity of the Hackensack valley, though not to be classed as valley drift in the strict sense of the term, there are some notable kames and associated plains. The most remarkable are northeast of Rivervale. Here there is a well-marked horse-shoe-shaped kame area, referred to in the Annual Report for 1892.* For this kame

* Page 93.

belt the name of *kame moraine* was suggested, both because of its moraine-like topography, and because there stretches southward from it a gravel plain comparable, in all respects, to an overwash plain outside a moraine. This plain connects with the sand and gravel of the Pascack, at Hillsdale. It declines regularly to the south, having an elevation of no more than forty feet at Oradell. It is also continuous with the stratified drift farther south along the Hackensack. It is interrupted at intervals between Rivervale and Randall by till hills which rise above it. The plain is further interrupted by the considerable valleys of the Pascack and Hackensack.

Below the coalescence of the Pascack, Saddle river and Hohokus gravel plains, the joint plain has a continuous decline to the southward. It connects with the valley drift of the Passaic at Hawthorn.

The average depth of the stratified drift in the northeastern part of the State, in the broad depressions between the Palisade ridge and the crystalline highlands to the west, is estimated to be about sixty feet. The depth, however, is by no means uniform. At Delawanna, in the valley of the Passaic, sand and gravel have been penetrated to a depth of 108 feet, or to forty feet below sea-level, without reaching rock. At Hackensack, in the valley of the same name, sand and clay have been penetrated to a depth of 215 feet, or to a depth about 200 feet below sea-level. At Oradell, sand and clay are reported to extend to a level 170 feet below that of the sea. Near Little Ferry, on the west side of the Hackensack valley, the surface of the rock lies 50 to 100 feet below sea-level. Between Englewood and Highwood, rock is said not to have been reached at a depth fifty feet below the level of the sea. Nearer the ridge, in the same latitude, the rock surface is sixty feet below the sea-level. At Closter, the surface of the rock at one point is known to be forty feet below the sea-level. These data are sufficient to indicate that the pre-glacial valleys of this region were much deeper than the present. They tell of an elevation greater than that of the present at some time preceding the last glacial epoch.

Stratified drift about the borders of the swamp at the head of Newark bay.—There is a narrow and discontinuous border of stratified drift along the highlands west of the marsh. It now and then takes on something of a terrace aspect. At Carlstadt, it is disposed as a terrace at an elevation of thirty-five feet. It occurs at a corresponding level south of Carlstadt, but does not here assume a distinct topographic

form. At Kingsland the sand and gravel of the Passaic extending south from Lyndhurst connect with the stratified drift along the border of the marsh. At Schuyler's Corners, south of the Arlington cemetery, there is a gravel ridge near the marsh, having a height of six to ten feet, which has the aspect of a ridge formed along the shore of a body of standing water. It may well be a beach line.

Stratified drift also occurs about the islands in the tidal marsh. One and one-half miles south of Secaucus, at the point of the island, and east of the Erie railway, there is a spit-like ridge having a maximum elevation of between ten and twenty feet. Just south of the Snake Hill station of the Delaware, Lackawanna and Western railway there is also a spit-like gravel ridge at an altitude of about ten feet. It is disconnected from the higher land east of the depot, from which the material must have been derived, were the ridge formed as a spit. It is possible that the break is artificial.

About Moonachie, there is stratified drift up to levels of twenty or thirty feet. In some places it is terraciform, while in other places its original disposition has been obscured by the action of the wind. The stratified drift at the west base of the Palisade ridge was described in the report for 1893,* and further reference to it need not be made here.

Decisive evidence concerning post-glacial submergence might have been expected about Newark bay. Unfortunately the evidence which is found is as equivocal as it could well be. The tentative conclusions reached by earlier studies are the best which can now be suggested.† If the sea-water stood higher than now, relative to the land, while the glacier ice occupied northern New Jersey and its surroundings, as seems possible, its rise above the present tide-level appears to have been slight, and may as well have been due to the attractive influence of the ice, as to sinking of the land. There is now no evidence at hand to show that it continued to stand above its present level, after the ice disappeared.

South of Newark stratified drift has little development except in the valleys of the Elizabeth and Rahway rivers. It is locally plentiful along these streams.

Between the crystalline highlands and the Palisade ridge there are

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* Page 195.

†Annual Report of the State Geologist for 1893, page 208.

many notable kames and kame areas. These have already been referred to at some length in an earlier report.* There are also a number of eskers in the region, most of which were referred to in the report just mentioned. The more notable ones were there described at some length, and further description will not be given here.

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*Annual Report for 1893, pages 84–95.

SECTION II.

THE GLACIAL STRIÆ OF NEW JERSEY.

Distribution.—Striæ occur at intervals throughout the whole of the area covered by ice during the last glacial epoch. So far as the record goes, they appear to be distributed very unequally. This apparent inequality is due chiefly to three causes—1°, the variation in the frequency of rock exposures, due (*a*) to the unequal thickness of the drift, and (*b*) to the varying frequency of excavations; 2°, the more rapid weathering of some rock surfaces than of others; 3°, the difference in the hardness and texture of the different rock formations, in consequence of which some were more readily striated than others.

The drift of New Jersey is thickest in the northern part of the State between the Palisade ridge on the east and the crystalline highlands on the west. This is the area of the Triassic formation. Within it, the drift is thicker where the underlying rock is sedimentary, and thinner where it is trap. This distribution of the drift is due to topography, not to variations in the character of the rock, though it is the hardness of the trap as compared with the shale and sandstone, which has given rise to the ridges. On the whole, striæ have been least frequently recorded where the underlying rock is the sedimentary part of the Triassic. This is due chiefly to the fact that the rock is so rarely exposed. The rock itself is not ill-adapted to receiving striæ, and it has been so generally covered by drift since the glacial epoch, that glacial markings cannot have been obliterated.

On the thinly-covered trap ridges of the same general area, recorded striæ are numerous. On the Palisade ridge they appear to be much more abundant toward the southern end than toward the northern. This is doubtless because there is a very much larger number of excavations in the former region. Throughout the State striæ appear to be much more frequently recorded along the roads than elsewhere. This is partly because the surface near the roads has been examined in more detail than intermediate areas, and partly because excavations are much more frequent in such situations than elsewhere. These facts illustrate the first point noted above, viz.: that the inequality of

the distribution of recorded striæ is due in part to the varying frequency of rock exposures, either natural or artificial.

The effect of weathering on striæ is well shown in the limestone belts. With very few exceptions striæ are not found on the limestone of Warren and Sussex counties. Outcrops are abundant, but the natural outcrops are, without exception, free from striæ. It is only where recent excavations made by human agency discover a surface of limestone which had been continuously covered since the glacial period, that striæ have been found upon it. It must be believed that striæ were very generally present on the limestone at the outset, since the rock is admirably adapted to receiving them. The conclusion that they have been obliterated by weathering in post-glacial time, except where efficiently protected, seems to be the only one to which the facts lead.

The surface of the crystalline schist weathers much more readily than the surface of the trap, the Hudson River formation, or the rocks of the Kittatinny and Green Pond mountain ranges. Over most of the crystalline schist area where rock exposures occur, they are natural. This means that the exposed surfaces have not been protected since the retreat of the ice, and any glacial markings they once possessed have largely disappeared. The crystalline schists are less well adapted to receiving scratches than some other sorts of rock, because of their superior hardness.

Recorded striæ are most abundant on the shale and sandstone belts of the western part of the State, and on the trap ridges. These formations seem to have been well adapted both to receiving and retaining the striæ.

The total number of localities where striæ have been recorded in Warren county is 35; in Sussex county, 77; on the crystalline highlands west of the Green Pond mountain range and east of Sussex county, 12; on the Green Pond mountain range, 7; on the crystalline highlands east of the Green Pond mountain range, 6; between the crystalline highlands on the west and the Hackensack valley on the east, 63, mainly on the trap ridges; on the Palisade ridge, 180. In all cases the records represent the average direction in the immediate locality of observation, if all striæ of that locality are essentially parallel. Where there are two or more notably divergent systems of directions, they are recorded separately. The 380 records of striæ for the northern part of the State by no means represent all that

have been observed. In many localities numerous closely associated rock exposures show striæ in directions so nearly the same that but a single record was made for the many.

Directions.—In general it may be said that the striæ upon the Palisade ridge indicate that the ice here moved considerably east of south. West of the Palisade ridge the striæ in general have a direction west of south. To this general direction there is a single locality which constitutes a notable exception to the rule. This is in the vicinity of lake Hopatcong, where the course of all markings is east of south. While the striæ over most of the State point somewhat west of south, the amount of westing varies greatly.

On the whole, the striæ show that the ice was influenced to some extent by the underlying topography, but that its motion was by no means strictly dependent upon topography. This independence clearly indicates that the thickness of the ice at the time of its maximum development was considerably more than enough to overtop the mountains of the northern part of the State. The easterly movement of the ice from the valley west of the Palisade ridge over the ridge itself, was a movement which must have taken place in spite of the obstacle which the ridge itself constituted to glacier motion in this direction. Along the Green Pond mountain range, as also along the Kittatinny mountain, the direction of movement was not parallel with the trend of the range. The same general relation is shown along the Watchung mountains. These several examples clearly illustrate the fact that the direction of movement was measurably independent of topography. The general direction of ice movement is shown on the accompanying map (Plate II.) The directions here indicated are considerably generalized, the scale of the map being too small to show the very considerable deflections occasioned by the larger topographic features.

In many localities striæ are found which are not parallel to each other. The varying directions may be seen on the same surface or on closely associated surfaces. On a given surface, the inharmonious linings may be arranged in two or more sets, each of which has a definite, measurable direction. In other cases there are striæ pointing in all directions between certain limits, and the degree of discordance may be great.

Discordant and crossing striæ.—Sharply crossing sets of striæ are relatively rare, though not unknown. Discordant striæ of the other

sort are frequently seen. These discordant and crossing striæ were probably made at different stages in the ice epoch, when the ice had somewhat different directions of movement. Local topographic features were much more effective in controlling the direction of motion when the ice was thin, than when it was thick. The ice must have been thin in each situation at least twice in the history of an ice sheet—once while the ice was developing, and once when it was disappearing. Between these two periods, the ice was relatively thick. The apparent lack of harmony in the directions of striæ at the east base of the Kittatinny mountain, and in some other comparable situations, is doubtless to be explained by the supposition that they were made at somewhat different times, and that each direction recorded represents a more or less temporary direction of movement.

Striæ west of the crystalline schist highlands.—The testimony of observed striæ on Kittatinny mountain and in the Kittatinny valley is such as to allow certain more or less detailed conclusions concerning the directions of the ice movement to be based upon them. These will be considered geographically from west to east.

1. West of the Kittatinny mountain the ice movement seems to have been approximately parallel to the strike of the formation, and to the trend of the more prominent topographic features, that is, about S. 40° W. So far as data show, deviations from this general direction seem referable to minor topographic features.

2. In Pahaquarry township, Warren county, and in the southern part of Walpack, where the Kittatinny mountain is only a narrow ridge, the ice moved across the top of the ridge in a direction somewhat more southerly than that of the trend of the ridge itself, and somewhat more southerly than in the adjoining part of the Kittatinny valley. The striæ here point from S. 11° W. to S. 25° W. (corrected), with local variations due to local topography.

3. On the northern part of the Kittatinny mountain, where the range widens out into a broad ridge or plateau, the direction of movement across the crest was radically different from that farther south. Striæ are not accessible over the larger part of the surface, but on the higher part near its eastern margin, they are abundant. At the eastern foot of the escarpment they are approximately parallel to the trend of the mountain, that is, about S. 40° W. Toward the summit of the mountain, the westing increases gradually. At the summit it

increases at a bound, and the striæ point, in one case at least, as much as *40° north of west.*

Though some of the extraordinary directions may be the result of local topography, the sudden westerly turning of the striæ on the crest of the ridge is a general fact. Many of the striæ pointing somewhat north of west are certainly not due to local deflection. When studied in relation to their associations, the striæ of this part of the mountain show that the ice was kept from moving so much to the west as it otherwise would, by the eastern escarpment of the mountain, and that so soon as it surmounted the crest, it yielded promptly to the westerly tendency.

4. Along the eastern base of the Kittatinny mountain, the ice-movement was approximately parallel to the trend of the escarpment, though the striæ are not all harmonious in direction. The base of a mountain range is just the place where direction of movement was likely to vary much during the history of glaciation. East of the base of the Kittatinny mountain, the westing of the striæ lessens, and throughout the western half of the valley the movement was more to the west than in the eastern half. Between the northern and southern ends of the valley, there is little difference in the direction of striæ in the west half, though the westing increases very slightly to the south.

5. Along the eastern and lower side of the Kittatinny valley, the movement was notably more southerly than over the higher slate hills along the western side. The average direction of the striæ along the eastern side of the valley is S. 18° to S. 28° W. (corrected). This is a direction considerably more southerly than the trend of the valley itself, or than the trend of the steep front of the high land bordering it on the southeast. If the striæ in the northern half of the east side of the Kittatinny valley be compared with those in the southern half, it is found that the former have an average direction 28° west of south, and the latter an average direction 20° west of south (the anomalous direction on Jenny Jump mountain not being included). These figures show that along the eastern side of the valley the motion was more westerly in the northern than in the southern half.

The diminution in the westing of the striæ from the west side of the Kittatiny valley to the east is still further emphasized when the striæ on the highland to the east are studied. On this highland the westing lessens, especially to the south, until it disappears altogether,

and about lake Hopatcong actually gives place to a slight easting. This means that near its limit, the motion of the ice was obliquely toward the Green Pond mountain, and essentially at right angles to the moraine close at hand.

Striæ on the crystalline highland area.—The glaciated part of the crystalline highland area is divided into two approximately equal parts by the Green Pond mountain range. On the western side of this range, striæ were found at but fifteen localities. Of these, three were not on the crystalline schist proper, but on the other formations which lie at the west base of Bear Fort mountain. They are so closely associated with the striæ of the crystalline schist area, that they are best considered in this connection.

The average direction of the striæ on the crystalline highland area west of the Green Pond mountain is about S. 10° W. The maximum westing is S. 45° W. at the south end of Clinton reservoir. The minimum westing is an easting of 27°. This occurs on the west side of lake Hopatcong one and a half miles southwest of Hurdtown. In the northern half of the crystalline schist highland area west of the Green Pond mountain range, the movement of the ice was considerably more to the west than in the southern half. The average direction of the striæ north of the lake is about 20° west of south, while the average direction south of the lake is about 14° east of south. Passing from north to south in this area, the striæ do not show a uniformly-decreasing westing. Within the northern half of the area there is very little difference in direction between the eastern and western portions.

Within this area there are a few striæ which do not appear to conform to the general direction. The most anomalous deviation occurs east of Dunker's pond, where the striæ point in a direction S. 7° E., whereas in the immediately-surrounding region all known striæ point considerably west of south. At other points, also, the striæ depart from the normal direction. These variations are probably the result of the different directions of movement of the ice in the same place at different stages in the history of ice movement. Distinctly-crossing striæ are found at but one point, viz., at the southwest end of Clinton reservoir. Here there are three sets with directions of S. 45° W., S. 30 W., and S. 10° W., respectively.

On the Green Pond mountain range itself, including Bear Fort, Kanouse and Copperas mountains, striæ have been recorded at but

seven localities. Their general course is west of south. The maximum westing is S. 57° W., a mile and a half north of Postville, on the east side of Bear Fort mountain. The minimum westing is on Copperas mountain near the Davenport mine, where the striæ have a direction of S. 3° E. The average direction for the entire range is about S. 17° W. The average direction for the northern part is S. 23° W., while for the south part of the range it is S. 5° W.

On the crest of the ridge there is a uniform decrease in the westing from north to south. At the north end, the direction is S. 22° W., near Terrace pond, while toward the southern end the directions S. 7° W. and S. 3° E. are found. This decrease in westing from north to south on the crest of the range is in accordance with the decrease in westing on the highland region west of the mountain, as shown above. On the whole, the striæ on the crest of the range have a westing considerably less than the trend of the mountains themselves. The maximum westing on the crest is S. 22° W., while the trend of the range itself is about S. 40° W.

On the west slope of the mountain, striæ were found in only two places. These were in accord with each otber, their direction being S. 42° W. The westing in these cases is much more considerable than that of the striæ on the highlands west of the range, and more considerable than that of the range itself. The westward slope of the range may be responsible for their apparent excess of westing.

On the east slope, striæ were found only north of Newfoundland. On this slope the westing increases to the south. This is contrary to the change in direction along the crest of the mountain, where the westing decreased to the south; but the number of striæ recorded on the east face of the mountain is so small that from them it is perhaps unsafe to generalize. A few of the striæ are worthy of note. In the latitude of Greenwood lake they have a course of S. 5° E. to S. 12° W. A little farther south; in the latitude of Cedar pond, the direction is S. 57° W. These recorded striæ are on the east slope of the mountain. In the first locality the direction is less westerly than the direction of the mountain range, and less westerly than most of the striæ in the same latitude west of the range. In the second locality, Cedar pond, the reverse is true. Here they have a greater westing than either the mountain range or the striæ on the highlands west of the range. No striæ were found on the summit in the same latitude, with which to compare these directions.

On the crystalline highlands east of the Green Pond mountain range, striæ were recorded in but six localities. Though frequently exposed, the rock is rarely striated. The average direction is about S. 20° W. The maximum westing is S. 62° W., north of Montville. The minimum westing is S. 10° W., one mile southwest of Midvale. Compared with the average direction on the Green Pond mountain range, the ice movement was more westerly east of the range than on it. Compared with the average direction of the striæ on the highlands west of the range and north of lake Hopatcong, the movement had nearly the same direction. On the whole, it would appear that the westing in this area increased slightly toward the Green Pond mountain, and that it also increased from north to south.

From a study of the striæ of the crystalline schist area as a whole, including the Green Pond mountain range, it seems that the striæ have rather less westing on the range than on either side of it; that they correspond much more nearly in direction in the northern half of the area, than in the southern; that in the southern half, on the west side of the Green Pond mountain range, the movement not only lost its westing altogether, but was actually to the east of south, toward the Green Pond mountain range itself; that on the east side of the Green Pond mountain range in the southern part of the area, the westing of the striæ increased. The movement, therefore, seems to have been somewhat toward the south end of the Green Pond mountain range from either side.

It will be observed that on the west side of the Green Pond mountain range, where the direction of the striæ is east of south, the latitude is essentially that of the south end of the mountain range. It is to be noted also, that the maximum westing of striæ found in the whole area is on the *east* slope of Bear Fort mountain, S. 57° W., a direction notably *more* to the west than the course of the range itself, although the general direction of striæ in the region is *less* westerly than the course of the mountain range.

Striæ west of the Palisade ridge and southeast of the crystalline highlands.—Within this area striæ are numerous, especially on the trap ridges. They have been recorded in sixty-three localities. They take the form both of minute scratches and well-developed grooves, though the former are more abundant than the latter. The average direction in this region, barring deflections which appear to be the result of local topographic features, is about S. 60° W. The

westing is rather greater in the northern part of the area than in the southern, a condition of things just the reverse of that which is true in the highland area to the west. Toward the southern portion of the drift-covered area, as the moraine is approached, the direction of the striæ seems to shift so as to assume a course approximately at right angles to the direction of the moraine.

The maximum westing in this region is S. 78° W., on the summit of the mountain west of Paterson. The minimum westing recorded is due south, at Mountain View, due probably to local topographic relations. In the northern half of this area there is very little difference in the direction between the eastern and western portions where striæ are recorded, but in the southern half, the westing is much greater in the western portion than in the eastern. Indeed, on Snake hill, some of the striæ point east of south. Within this area the trap ridges had much influence, locally, in determining the direction of ice movement at the time when the recorded striæ were made. Thus at the eastern base of that part of Third mountain lying southwest of Mountain View, the striæ have a direction S. 15° to S. 27° W., while on the west side of the same mountain they range from S. 57° to S. 62° W. The striæ on Second mountain have a similar behavior. Snake hill also exerted a diverting influence on the ice, and the discordant directions on various parts of that hill are doubtless due to its own deviating influence.

Comparing the striæ of this area with those farther west, it is to be noted that the striæ southeast of the crystalline highlands have a westing considerably greater than that of the striæ on the highlands themselves.

Striæ on the Palisade ridge.—On the Palisade ridge recorded striæ are very abundant. They are found in all latitudes from the northern boundary of the State to Bergen Point. With the exception of the few striæ at the western base of the ridge toward the south end, the striæ all point east of south. The easterly divergence is more toward the north end of the ridge than toward the south. The decrease in easting is from S. 74° E. in the latitude of Closter and Alpine, to S. 43° E. in the latitude of Hoboken, an average decrease of something like 30°.* The striæ not only change their course from north to south along the ridge, but their direction stands in some

* For full account of the striæ of the Palisade ridge see report of State Geologist for 1893, pages 61–176.

relationship to the altitude of the ridge. In general the easting increases toward the top, in which position it is greatest. The change in the direction of striæ with increase of altitude, on the west face of this ridge, is in every way analogous to the change which has been noted as occurring on the east face of Kittatinny mountain.

Varieties of glacial markings.—By far the larger number of recorded directions of ice movement are the records of small striæ. Deep grooves are relatively rare. Chatter marks are not frequent. Smoothed and polished surfaces, which do not tell of the direction of ice movement, are rather common. The greatest variety of glacial markings known is found upon the Palisade ridge. This is partly because this ridge has been studied in more detail than most other areas with reference to this point, and partly because excavations are here so frequent that the glacial markings are well exposed. The various forms of glacial markings which are found on this ridge have already been described.*

*Loc. cit., p. 170, *et seq.*

SECTION III.

CHANGES IN DRAINAGE—LAKES—CHANGES IN THE COURSES OF STREAMS.

With a single exception, the larger streams of the glaciated area of New Jersey follow approximately the drainage lines established before the advent of the glacial period, or at least before the advent of its last epoch. The single exception is the Passaic system. The drainage from this basin bears little resemblance to that which existed before the disturbing influence of the ice made itself felt.

The reasons for the general immunity from change in the case of most of the streams of northern New Jersey may be readily pointed out. In the first place, most of the valleys of the glaciated portion of the State were parallel, or essentially parallel, to the direction of ice movement. In this position, glacial erosion tended to emphasize them, rather than to make them less marked. Had their courses been at right angles to the direction of ice movement, or even oblique to it, the disturbing influence of the ice would have been much greater. In the second place, most of the valleys were deep. The considerable elevation of the region, together with its mature drainage, had determined this point. Deep valleys are less readily obliterated, either by erosion or by filling, than shallow ones. In the third place, the rock in which they were cut is, on the whole, hard, and hard rock yields to the erosion of glaciers much less readily than soft. Deep valleys in soft rock would stand much better chance of obliteration, other things being equal, than corresponding valleys in hard rock. In the fourth place, the thickness of the drift over most of northern New Jersey is rather slight, so slight as to fail to fill the valleys which pre-glacial and glacial erosion had excavated. When the ice receded, therefore, the valleys still remained, and along them drainage re-established itself. Had the thickness of drift been great, the result might have been different. The hardness of the rock had something to do with the paucity of the drift. Lastly, the terminal moraine, which represents the thickest belt of drift in the State, crosses few of the important drainage lines. For these reasons, the larger pre-glacial valleys are also the post-glacial lines of drainage.

With these general principles in mind, more specific reference may be made to the existing drainage. In the northwestern part of the State, all the main valleys, and many of the minor ones, were excavated in pre-glacial time. In many cases the position of the streams in the valleys, and in some cases the direction of drainage, is not the same as before the ice invasion. The "rifts" in the Delaware probably indicate, in some cases at least, that the river has been locally shifted from the center of the rock valley to one side, and thus superimposed upon the rock slopes.

The number of cases in which reversals of drainage can be affirmed, is small. The best-marked case is in the Flat brook-Mill brook valley, near Montague. The valley is here greatly obstructed by morainic accumulations.* Just north of the moraine a stream (no name) flowing down the slope of Kittatinny mountain and crossing the Flat brook-Mill brook valley nearly at right angles, has cut through the narrow ridge separating this valley from the Delaware. The position of the stream across this ridge was determined by a sag, the elevation of which was nearly the same as that of the surface of the gravel deposits in the Flat brook-Mill brook valley. The stream has cut a narrow, steep-sided gorge through this ridge to a maximum depth of forty to fifty feet, all but four or five feet being in rock. In pre-glacial time, the streams which flowed down the slope of Kittatinny mountain did not enter the Delaware directly, but joined the stream which then occupied the axis of the Flat brook-Mill brook valley.

Through its entire length this valley has been filled to an unknown depth with stratified drift. As now, so in pre-glacial times, the drainage of this valley was partly to the northward and partly to the southward, a low divide separating the two parts. In spite of this, it is extremely doubtful whether the divide corresponded in position with that which now separates the two streams. It is probable that it was farther south, thus increasing the length of Mill brook, at the expense of Flat brook.

The round-about course of the upper part of Paulins kill from Newton, via Lafayette and Augusta, is probably entirely post-glacial. It is probable that the headwaters of Paulins kill lay to the northeast of Augusta in pre-glacial time. The sharp turn of the Papakating creek, two miles northeast of Augusta, is probably due to direct

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* See ante, page 20.

obstructions in the southwest-northeast valley at that point. It is probable that before the last glacial epoch that part of the Papakating creek above the bend was tributary to Paulins kill. It may well have been the upper part of the Paulins kill itself. This is, however, largely hypothetical, as no conclusive evidence is at hand. Judging from surface indications along the Papakating creek northeast of Papakating station, and also in the vicinity of Roy's station, it may well be that the pre-glacial divide between the Paulins kill and Papakating was some miles northeast of Augusta. The drainage along the valley from Newton to Branchville Junction probably joined the Pequest system, though by a route which is not now known.

Along the Pequest river a few changes can be made out. The winding course of the river northeast of Danville is due to the obstruction of the valley by the terminal moraine. The pre-glacial course was probably in a more direct line from a point just above Danville to Townsbury. The round-about course of the upper part of this river, from near Hunt's Mills through Bear swamp to Springdale, and then southward, is quite certainly not the pre-glacial course, although it is impossible to locate definitely the earlier drainage lines.

In default of borings, it is impossible to say whether the pre-glacial drainage of the Germany Flats valley was northward into the Wallkill valley at Hamburgh or southward into the Pequest valley. Judging by the relative width of the valley in various parts, the drainage of that part now occupied by Germany Flats was probably northward along the present course of the Wallkill.

The pre-glacial drainage of the Wallkill valley was northward. This is clearly indicated by the increasing depth and width of the valley in that direction. The same is true of Vernon valley, though its head may not have been so far south as at present.

In the central part of the State the drainage outside the moraine was disturbed at a number of points. The area occupied by Budd's lake is believed to have drained to the north in pre-glacial time. This northern outlet was blocked by the moraine just north of the lake, giving rise to the lake, which then overflowed the lowest point in its rim, and its surplus waters found escape via the South Branch to the Raritan. The other notable change in drainage in this region has to do with the Black river. As stated in

a previous report,* the present course of this river is believed to be, in some sense, post-glacial. The valley which it occupies is a pre-glacial valley, but the drainage through it has been reversed. North from Hacklebarney, two miles southwest of Chester, the pre-glacial drainage through this valley was to the north, joining the Rockaway north of Kenvil. Near its point of junction with the Rockaway, the moraine filled up the valley in such wise as to obstruct drainage in this direction. The waters which had heretofore reached the Rockaway were ponded back above the point of obstruction. They rose until they found escape to the south, in which direction they have continued to flow. The valley from Hacklebarney southward was a pre-glacial valley. The divide between it and the headwaters of the northward-flowing stream was a low col, across which the waters found their escape after the moraine was formed.

On the highland area of northern New Jersey, the changes in drainage effected by the ice are minor. In some cases the streams were shifted about to a slight extent in their courses. This resulted from the partial filling of the valley bottoms with stratified drift. The post-glacial streams chose the lowest courses open to them at the close of the deposition of the drift, without reference to the position of the axis of the valley. It is doubtless true that many ravines and very small valleys on the slopes are filled up so as to give no surface indication of their existence. The covering of drift in this region is so slight, however, that no considerable pre-glacial valleys are believed to be concealed.

East of the highland area, data concerning the courses of the pre-glacial streams are meager. The altitude of the country is here not great, and the drift is relatively thick. More commonly than otherwise, artificial excavations have not penetrated so deep as to reach its bottom, and little can be said, except in a general way, concerning the course of the drainage before the drift was deposited. It is reasonably certain that the streams had courses corresponding in general direction with those now in existence, but the details of their courses may have been very different.

Robinson's brook, a tributary to the Rahway river, flows through a valley which is largely of post-glacial origin. The Rahway

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*Annual Report of State Geologist, 1893, p. 150.

itself does not follow, throughout all its course, a pre-glacial line of drainage, though it does so in part.

On the west face of the Palisade ridge many ravines and trivial valleys may have been filled up by drift, so as to give no surface indication of their existence. At a few points their existence has been shown by borings.

By far the most important changes in drainage effected by the ice and its deposits were in the basin of the Passaic. The extremely circuitous course of this stream cannot fail to attract attention. Having its sources at various points from Mendham to Morristown, the waters of the system flow southward and westward, escaping from the area of the Great swamp through a narrow gorge across Long hill, at Millington. After escaping from the Great swamp, the river follows the depression between Long hill and Second mountain, to Stanley, where it crosses the line of the moraine. From this point its sluggish waters find their way northward by an irregular course through Hatfield swamp and Great Piece meadows. Then, turning east, the stream escapes across the Orange mountains, through gaps at Little Falls and Paterson. Thence its course is southward to Newark bay. There is hardly another river of equal size which has so irregular and unnatural a course.

It seems probable that in pre-glacial time the headwaters of the Passaic were in the vicinity of Mendham, as now, and that the drainage flowed thence eastward through the area of Great swamp, across the present site of the moraine, somewhere between Madison and Chatham, thence southeastward across First and Second mountains, via Short Hills and Millburn, and eastward to the sea. The facts on which belief in this course is based, were stated in the last report,* in connection with the history of Lake Passaic. As there stated, there is a deep drift-filled gap across Second mountain near Short Hills, the bottom of which is known to be not more than 170 feet above the level of the sea. Between First and Second mountains, in line with the drift-filled gap in Second mountain and the broad gap in First mountain at Millburn, the surface of the rock is known to be not higher than the level of the sea. It is almost certain, therefore, that the rock bottom of the notch in Second mountain is very much lower than the figure indicated above. These facts seem to indicate clearly that in pre-glacial time the drainage of the Great swamp area fol-

* Annual Report of the State Geologist for 1893, page 304.

lowed a much more direct course to the sea than now. The drainage from a large part of the area north of Short Hills probably joined that of the stream which found its way to the sea by the Short Hills and Millburn gaps. It is uncertain whether the Rockaway river flowed to the south and joined this system, or whether it turned east, south of Horse Neck, as now, and escaped across the mountains via Little Falls and Paterson. The latter is the more probable.

One other notable drainage change should perhaps be referred to in this connection, although it lies altogether outside the glaciated area of the State. This is in the course of the Raritan river. As stated in the Annual Report for 1892,* there is much reason to believe that at some early time the Raritan river, following its present course to a point midway between Somerville and Bound Brook, turned thence southward up the present valley of the Millstone, following that valley to its junction with Stony brook, thence up the valley of Stony brook, and across the low divide which separates it from the Shipetaukin, thence down the Shipetaukin and Assanpink valleys to the Delaware. The date of the reversal of this drainage has not been fixed. It may have been as late as the last glacial epoch, or it may have been somewhat earlier. Quite certainly it occurred within the Pleistocene period.

THE LAKES OF NORTHERN NEW JERSEY.

One of the most conspicuous effects of the changes in drainage due to the ice of the glacial period is to be seen in the great abundance of lakes, ponds and meadows in northern New Jersey. Many of the marshes and meadows represent extinct lakes. Many of the lakes, both existent and extinct, came into being as the direct result of interference with drainage. They may, therefore, be properly considered in connection with the changes in drainage effected by the ice.

The lake and pond basins of the glaciated area of the State belong to several distinct classes. These are as follows: (1) Limestone sinks; (2) rock basins produced by glacial erosion; (3) basins produced by the obstruction of river valleys by means of the drift; (4) depressions in the surface of the drift itself; (5) basins produced by a combination of two or more of the foregoing; (6) lakes and ponds

* Annual Report of the State Geologist, 1892, p. 124.

produced by artificial means. The fourth class, as specified above, may be subdivided into two or three divisions, viz., (*a*) depressions in the surface of the terminal moraine; (*b*) depressions in the surface of the ground moraine; (*c*) depressions in the surface of the stratified drift.* Since the stratified drift in which the lakes of this last subclass lie is largely in valleys, it would not be altogether inappropriate to class them with the third group specified above.

In some cases it is not possible to say with absolute certainty that the basin of a given lake or a pond belongs to one or another of the foregoing classes. It frequently happens that available data are too insufficient to make it possible to determine all elements involved in the origin of a given basin. Nevertheless, most of the lakes and ponds of northern New Jersey can be classified in one or another of the foregoing groups with a reasonable degree of certainty.

1. *Limestone sinks.*—In northern New Jersey there is one small pond which occupies a depression caused by the collapse of an underground cave in limestone. This lies three-quarters of a mile northeast of Blairstown, near the point where a road turns south to Paulina. The pond is very small and shallow. As a body of water it is insignificant, but it has some interest as a representative of one type of lake basin. The basin occupied by this little pond has been deepened in post-glacial times. The bottom of the sink is fully sixty feet below the highest point at its rim. Five or six feet from the bottom, the slope of the sink changes abruptly, becoming very steep below. This would seem to indicate a sinking of the bottom of the pond to the extent of five or six feet since the ice departed. Sink-holes of like origin are occupied by marshes at various points.

2. *Rock basins produced by glacial erosion.*—A second type of lake basins which finds representation in northern New Jersey is the rock basin produced by glacial erosion. It cannot be affirmed that there is more than a single representative of this class of lake basin in New Jersey, though there are several lakes which may possess such basins. In these cases the uncertainty is due to the fact that decisive data are not available. It is often no easy matter to prove that a lake occupies a rock basin, even when such is the fact. To establish a case beyond doubt, it must be shown, either by outcrops or by borings, that the rock rises at all points about the lake higher than the deepest part of its basin. Where the drift is thick, and especially where borings are wanting or few, it is often impossible to make this determination.

Even if a rock basin be demonstrated, it may be very difficult to prove that it is the result of glacial erosion. A rock basin may be produced by local subsidence, or by deformation of the strata in which it occurs. Between rock basins so formed, and those formed by glacial erosion, it may be impossible to distinguish, in a region which is heavily covered with drift. A rock basin may be greatly deepened by having its borders built up by drift. In such cases it is often difficult to determine to what extent the basin is really a rock basin, and to what extent it is a basin hemmed in by surface accumulations.

Sand pond, on Hamburgh mountain, quite certainly has a rock basin. This pond lies two and one-half miles east of Hamburgh. It is triangular in shape, and on three sides is surrounded by high hills where ledges of rock are so abundant as to preclude the possibility of a drift-filled outlet. At the western end, the bordering surface is lower, and here the pond has its outlet. Along this outlet the outcrops of rock are so abundant, and so disposed, as to show that solid rock occupies a level higher than the bottom of the lake. The maximum depth of the pond is probably not more than forty feet, and its average depth is probably not more than half this figure.

Sand pond, west of Coleville, may have a rock basin, but this is not beyond question. At its southern end there is so great a body of drift that, in the absence of borings, certain determination of the nature of the basin is impossible. Cedar lake, near Blairstown, is closely hemmed in by high rock ledges on either side. It may occupy a rock basin, but there are considerable masses of drift at either end of the lake which greatly deepen the basin, even if not entirely responsible for it.

3. *Basins produced by the obstruction of river valleys by means of the drift.*—The basins of the larger number of lakes in the glaciated part of New Jersey were formed by the obstruction of river valleys. To this class belong the following:

In Warren county.—Allamuchy pond, Glover's pond, Cedar lake (possible rock basin), White pond, Sunfish pond, Catfish pond, Shuster pond, Mud pond (Hardwick township) and Sand pond. Here also may belong Silver lake and Mud pond (Hope township), though they may belong to the next class.

In Sussex county.—Catfish pond, Sucker pond, Quick pond, Mud pond (Stillwater township), Swartswood lake, Hunt's pond, Little

pond and two unnamed ponds northeast of it, Long pond (Frankford township), Culver's pond, Sand pond, near Coleville (possible rock basin); Long pond (Walpack township), Round pond, Mashipacong pond, Lake Marcia, Decker pond, Roe pond, Mud pond (Vernon township), Wawayanda lake and Laurel pond. It is altogether possible that some of these lakes may have rock basins, but there are none of them which, in the light of present knowledge, may not be accounted for by the drift-filling which blocks one or both ends of the more or less elongated valleys in which they lie.

In Morris county.—Green pond, Lake Kinnelon (Stickle pond), Budd's lake, Split Rock pond and Lake Hopatcong.

In Passaic county.—Hank's pond, Macopin lake, Terrace pond, Greenwood lake, and Negro pond. It is very probable that some other small ponds belong to this category, and there are other lakes which may owe their origin in part to the blocking of valleys. If so, the valley-blocking does not appear to play the most conspicuous part in the formation of their basins.

The drift which blocks the valleys, giving origin to the lake basins, is sometimes stratified and sometimes unstratified. Many of the valleys are blocked at one end of the lake only, while others are blocked at both. North of the moraine, one lake only appears to owe its existence to the blocking of a river valley by the moraine itself. This is Green's pond, in Warren county. Outside the moraine, there is likewise a single lake which owes its origin to the damming of a valley. This is Budd's lake, in Morris county. Though the lake now drains to the south, its site is believed to have drained to the north, before the last glacial epoch. Blocked by the moraine just above the lake, water accumulated in the valley above, until it overflowed the divide to the south, finding its escape in that direction. The lake's northern shore does not reach the moraine, though it does reach the stratified drift outside it.

4. *Lakes in drift depressions.*—The number of lakes and ponds occupying depressions in the surface of the unstratified drift is not large. To this class can be referred with confidence only a few small ponds which have not individual names. The pond east of Llewellyn Park and south of the railroad, Essex county, appears to belong to this class. Here also belong some of the small ponds on Palisade ridge, in Hudson county. At various points along the terminal moraine there are small ponds which likewise belong to this

category, but they are too small to merit separate mention in this connection. Some of the lakes elsewhere referred to may belong to this category, as already noted.

There is a very much more considerable group of lakes which might, with almost equal propriety, be put into the class of lakes occupying basins formed by the obstruction of river valleys, or into the class of lakes occupying basins in the surface of the drift. The lakes of the group here referred to lie in depressions in drift which is for the most part stratified, the drift itself being in valleys. The lakes of this sub-class are believed to represent the sites of huge blocks of stagnant ice, which lingered in the valleys after the edge of the main ice sheet had retreated some little distance beyond them to the north. Stratified drift was deposited in the valleys about these ice blocks, while glacial drainage still coursed through the valleys. After glacial drainage had ceased to flow through the valleys concerned, the ice blocks melted, leaving depressions to mark their former existence. Such lake basins are due to the presence of stagnant ice masses, about which were laid down the deposits which now constitute the sides of the basins.*

The lakes which are thought to belong to this class are the following:

In Sussex county.—Buckmire pond, Turtle pond, Muckshaw pond, Stickle pond, Davis pond, White's pond, Hewitt's pond, Long pond (Andover township), Iliff's pond, Howell's pond, Drake's pond, White lake (Sparta township), Mud pond (Sparta township), Lake Grinnell (Lane's pond), and Wright's pond.

In Passaic county.—Franklin lake, the ponds west of Wyckoff, and the pond near Preakness.

In this connection, especial mention should be made of the chain of lakes, ponds and marshes in Sussex county, which extends from Turtle pond, near Huntsville (Green township), almost continuously to Lake Grinnell, a distance of eleven miles. The Lehigh and Hudson River railroad follows the chain of depressions between these points, and from it good views of the depressions can be had. It is believed that a succession of huge ice blocks lay in this valley while the main ice front was a little farther north, and that drainage from the main ice sheet to the north coursed through the valley, depositing sand and gravel about and among them. In some cases the ice masses

*Annual Report of the State Geologist for 1893, page 154.

were doubtless completely buried. They probably persisted until glacial drainage ceased to flow through the valley, that is, until the ice sheet had retreated beyond its head. Their melting then gave rise to basins, the larger of which are now occupied by ponds or lakes, while the smaller gave origin to marshes only.

Many of these lakes contain more or less white shell marl, the result of the accumulation of shells, mainly of snails. The white marl is known to occur in at least seven of them, viz., Buckmire pond, Turtle pond, Davis pond, White's pond, Drake's pond, Mud pond and White lake. In some of these the marl can be seen from the shore, but its extent and depth are generally unknown.

5. *Combination types.*—A very considerable number of lakes occupy depressions which do not fall into one or other of the foregoing classes. They are depressions which are partially bounded by drift, and partially by rock. They are due to the disposition of the drift with reference to rock elevations. It is possible that they are in many cases produced by the obstruction of valleys by means of the drift, but if so, this relationship does not clearly appear. To this type belong the following lakes:

In Sussex county.—Stag pond, Morris pond, and Losee pond.

In Passaic county.—Tice's pond, Rotten pond, Mud pond, Sheppard's pond, and the pond on First mountain, south of Paterson.

In Morris county.—Dixon's pond.

6. *Lakes formed by human agency.*—There is a very considerable number of lakes or ponds or reservoirs produced through human agency, by the obstruction of natural drainage lines. In this class fall Clinton and Oak Ridge reservoirs, Hopewell pond, Petersburg pond, Durham pond, Denmark pond, Cranberry reservoir and Stanhope reservoir.

A considerable number of the lakes which have been mentioned in the foregoing pages, have been increased in size by the raising of the outlets, as for example, Lake Hopatcong. The aggregate area occupied by the natural lakes and ponds within the glaciated area of New Jersey, including also Budd's lake, which is just outside the moraine, is about sixteen square miles.* Of the total area, Lake Hopatcong occupies about one-fourth, and Greenwood and Swartswood lakes nearly another fourth.

The average depth of the lakes of New Jersey is not great. Morris

* Vermeule. Geological Survey of New Jersey, I., 1838, pages 109–111.

pond has a depth of 110 feet. Long pond (Andover township) and Wawayanda lake are reported to have maximum depths of about 100 feet each, but their average depths are considerably less. By far the larger number of lakes have depths of less than fifty feet, and many of them much less.

In altitude, the lakes vary greatly. Aside from the artificial lakes and ponds, and aside from some very small ponds which have not individual names, the lowest lake is Cedar lake, in Sussex county. This has an altitude of 384 feet. The highest lake is Lake Marcia, which has an elevation of 1,574 feet. The lakes of northern New Jersey, therefore, have a vertical range of nearly 1,200 feet.

Many of the lakes which had a temporary existence, but which have now become extinct, have been referred to in connection with the stratified drift deposits of the earlier part of this report. Here may be mentioned—1°, the Pequest lake; 2°, a long, narrow lake which probably had a temporary existence in the valley of the Black river from Kenvil to Hacklebarney; 3°, Lake Passaic, which at the time of its maximum expansion had an area twelve to fifteen times as great as that of all the existing lakes of the State; and 4°, the several shallow lakes which occupied the deeper part of the basin of Lake Passaic after that lake was drained. These lakes have been referred to in another connection* and need not be discussed here. Many smaller lakes or ponds had a temporary existence and have left slight records of themselves.

*Annual Report of the State Geologist for 1893, page 317.

SECTION IV.

POST-GLACIAL CHANGES WITHIN THE GLACIATED AREA.

EROSION.

The amount of post-glacial erosion which has been accomplished in northern New Jersey is, on the whole, exceedingly small. In many places the streams appear not to have lowered their channels at all, while in other places they have affected more considerable results. The irregular disposition of the drift, which nearly filled the valleys at certain points and left them nearly free from drift at others, gave occasion for these variations in their subsequent work. Where a body of drift was deposited across a valley, drainage through the valley was ponded behind it. As the ponded drainage overflowed the drift barrier, it had high velocity and quickly cut down the dam. On the whole, however, the surface of northern New Jersey remains very much as it was at the time of the retreat of the ice. A few words may be added concerning the erosion along the various valleys.

Along the Delaware.—Post-glacial erosion in the valley of the Delaware has been much more considerable than in any other valley of northern New Jersey. In general it may be said that the river has cut its channel from the level of the highest gravel terraces to its present bed. In the narrow parts of the valley, as at the Water Gap, where the terraces are absent, post-glacial erosion has been sufficient to remove all the gravel originally deposited there. At Columbia, the vertical erosion has been about seventy feet; at Browning, about sixty-five feet; below Walpack Bend, about eighty feet. Above Decker's Ferry, gravel terraces occur 100 feet above the river, but as there are some indications that stagnant ice lay here while this high-level gravel was being deposited, erosion may not be so great as would be indicated by this figure. It is, however, at least more than forty feet. At Walpack Center, post-glacial erosion has been more than 100 feet; at Dingman's, about 120 feet; west of Hainesville, about 100 feet; below Montague, about 120 feet; oppo-

site Mashipacong island, about sixty-five feet; near the State line, about eighty feet.

The width of the flood plain is in some sense a measure of the width of the passage cut in the drift-filling of the pre-glacial valley in post-glacial time. In several places on the Jersey side, the flood plain has a width of half a mile. Where it is wide on one side of the river, it is commonly narrow or wanting on the other. Above Walpack Bend, the width of the post-glacial valley would average from half to three-quarters of a mile. Below the Gap the trench is much narrower. The height of the flood plain is often from twenty to thirty feet above the river.

The erosion in the Delaware valley below the moraine was referred to in the Annual Report for 1892.

In the valley of the Flat brook.—The amount of cutting done by theFlat brook in post-glacial time, is very variable in different parts of the valley. As the ice retreated, the irregular filling of the drift gave origin to local lakes and ponds along the valley, and drainage through it has removed the obstructions between these lakes and ponds, giving rise to an uninterrupted stream. The amount of cutting between the ponds and local lakes depended on the height of the drift barriers. Where these barriers were low, the cutting has been slight. Where they were high, the amount of erosion has been considerable. In places near Flatbrookville, the amount of cutting (vertical) may have been as much as sixty feet; near the first bridge above Flatbrookville, seventy feet; a quarter of a mile below the second bridge, forty feet; while at the second bridge above the village, the cutting has not been more than eight feet. From this point to Peters Valley, the stream meanders on a broad, flat plain, formerly a swamp or lake, which the stream has actually been silting up. Here, therefore, there has been no post-glacial erosion. Midway between Peters Valley and Layton, the stream has cut a trench seventy-five yards wide, and more than twenty-five feet deep across the barrier of gravel which separated two large depressions in the valley. Above Layton, the maximum cutting has nowhere been more than thirty feet, and in general it has been much less.

Along the Mill brook.—In the Mill brook valley there has been practically no erosion in post-glacial time. The stream, on the contrary, has been silting up its marshes throughout most of its course.

In the valley of Paulins kill.—As in the Flat brook valley, the

amount of post-glacial erosion along this stream varies greatly within narrow limits. In a few cases only is there positive evidence of even a moderate amount of erosion. Jacksonburg creek, below Blairstown, has trenched the Paulins kill gravels to a depth of twenty-five feet, the trench having a width of about 225 feet. Along Blair's creek, above Blairstown, the vertical cutting has been as much as forty-five feet in some places. Above Paulina, the kill has cut thirty feet into the till, and a mile and a half above Stillwater, a small tributary has eroded a channel in the gravel deposits to a depth of twenty-five feet. Below Emmons station, the kill has cut thirty-five feet, and at Balesville the moraine has been incised to a depth of forty feet. In many other places, as above and below Stillwater, and at Yard's creek, near Hainesburg, there has been practically no erosion, but filling instead.

In the Vernon valley.—There has been little post-glacial erosion in the Vernon valley. The creeks draining the valley have been engaged rather in filling up the marshes through which they find their way.

In the Papakating valley.—Along the Papakating there has been very little erosion. Here and there the stream has cut a few feet. Where the Little Papakating crosses the high Papakating terrace southeast of Woodbourne, it has excavated a trench 80 to 100 feet deep and 200 yards wide. This it was able to do because of the great height of the terrace above Papakating. North of the Woodbourne school house, the stream has trenched the terrace to a depth of fifteen to eighteen feet in some places, while in closely adjoining parts of its course, it has done no cutting.

Along the Wallkill.—This stream has done some little erosive work in post-glacial time. The only point where any considerable lowering of the channel seems to have been effected, is at Ogdensburg, in connection with the remarkable gravel ridge at that point. This has already been referred to.*

Along the Pequest.—The greatest amount of erosion to be found along the Pequest or its tributaries, is where the stream crosses the moraine, between Danville and Townsbury. The maximum vertical cutting is about forty-five feet. Above this point, the Pequest and its tributaries have done little or no eroding since the ice departed.

**Ante*, page 39.

In the Rockaway valley.—There has been a very considerable amount of erosion in the Rockaway valley at certain points, notably from Powerville to a point somewhat below Boonton. Here the river has lowered its valley in the till as much as 100 feet in some places. Elsewhere it has done little erosive work since the deposition of the drift.

In the Pequannock valley.—From Copperas mountain to Butler, the Pequannock river has sunk its valley in the till to a depth of twenty to forty feet. Elsewhere its work has been slight.

In the Wanaque and Ramapo valleys.—These streams have done little eroding since the glacial epoch. The Wanaque has cut a trench in the gravel and sand fifteen to twenty feet in depth, from Pompton to a point above Wanaque. The Ramapo has likewise locally cut a trench twenty to thirty feet deep, and in places below Oakland, it may possibly have cut more; but on the whole, the erosion of these streams has been very slight, and has been confined chiefly to the removal of the barriers of gravel which separated the depressions left by the ice.

Along the Pompton valley.—The Pompton river has lowered its channel about fifteen feet in the gravel and sand plain about Pompton. South of Pequanac, it has done little or no cutting.

The Passaic valley.—Above Little Falls, the Passaic has done little erosion. Only here and there, as at Stanley, has it lowered its channel notably. For a considerable distance above Little Falls, it wanders throughout a wide extent of land which it has been unable to drain. Below Paterson, the river has lowered its channel thirty or forty feet locally, though this is much above its average.

The Saddle river.—The amount of erosion in the Saddle river is comparable to that in the valleys of the Wanaque and Ramapo.

In the Hackensack, Pascack and Tienekill valleys.—From the State line to its junction with the Pascack, the Hackensack river has lowered its channel, on an average, less than fifteen feet. In many places no cutting at all has been accomplished. South of the junction of the Pascack, the channel has been lowered ten to thirty feet. The erosion in the valley of the Pascack is in keeping with that of the Hackensack. The Tienekill has done no erosion, and is still wandering about in a marsh which was left when the ice disappeared.

THE ALLUVIAL DEPOSITS.

Most of the streams of northern New Jersey are bordered by alluvial deposits of greater or less extent. These are coarser where the streams are swift, and finer where the streams are more sluggish. The alluvial deposits have considerable development in many of the low flat lands or marshes where lake basins failed of development on the melting of the ice. This is conspicuous along many of the valleys, where the flood plains are very variable in width. The flood plains are now narrow, representing the width of the channels cut since the glacial epoch, and now wide, representing the areas over which the streams have simply deposited thin layers of silt, on the low lands left as the ice melted. Nothing is more striking in connection with the rivers of northern New Jersey, and especially of Sussex and Warren counties, than the fact that their flood plains are of such unequal widths in closely-associated parts of the valleys. This is well shown along the Wallkill, from Sparta to Ogdensburg, and along the Flat brook valley in the vicinity of Peters Valley, and several miles below. The broad alluvial plains which border some of the streams of the basin of Lake Passaic, are hardly of fluvial origin. They have merely been silted over by streams.

If the Delaware valley be excepted, alluvial plains have, on the whole, least development along the streams which have done the most cutting, and along such streams they have the least development where the cutting has been most extensive.

The height of the alluvial deposits above the present flood plains is variable, depending upon heights to which the floods reach. The highest are perhaps in the Pequest valley, near its junction with the Delaware. The alluvial deposits here reach an elevation of about thirty feet above the ordinary water-level in the Pequest. In general, the height of an alluvial plain above the stream it borders is greater along a large stream than along a small one. In some of the valleys there are alluvial plains which are on the point of becoming terraces. In such cases the streams have sunk their channels so far below the alluvial plains that they are flooded only during extreme high water. The streams are still eroding, and will presently have cut their channels so low that the alluvial plains will cease to be flooded at all, and will then pass from the category of flood plains, into the category of terraces.

East of Warren and Sussex counties, the larger streams often have alluvial plains of variable width. These plains are usually more or less discontinuous. In general they are not the results of the streams' own work, but rather the result of the flooding of flats which were left when the ice retreated. But little material has been deposited upon them by the streams since the ice deserted the region. On the other hand, the streams have been too sluggish to cut channels in them to such depths that they are not flooded annually.

PEAT AND MARL.

The flood plains of many of the stream are swampy, as they have been ever since the ice left the region. Along many of the valleys it is often difficult to differentiate the alluvial plains from the peat and humus deposits. Indeed, along many of the valleys, alluvium and peat are commingled in all sorts of proportions. This may be seen in the Pequest meadows. Before draining, these meadows were distinctly marshy. Since draining, cultivation has shown that the material of which the soil is composed is by no means wholly organic. This meadow shows all possible gradations from alluvium to humus. Similar conditions exist in the valleys of the Passaic and Rockaway above the Watchung mountains, and to a less extent along the Saddle, Pascack, Hackensack and Tienekill valleys farther north.

Peat bogs of some slight extent occur, but there are very few that are free from sediment washed in as the vegetable material accumulated.

Marl deposits are known to occur in many of the ponds, and beneath the humus and silt of many of the streams of Warren and Sussex counties. These deposits were carefully studied many years ago under the direction of Professor Cook, and somewhat full notes upon them were published in the Annual Report of the State Geologist for 1877, and in the Annual Report of the New Jersey Board of Agriculture for the same year.

CHANGES OF LEVEL.

The basin of the Passaic has been deformed since the water stood at its maximum height. The highest point of the shore line of the maximum stage of the lake is near the northeast end,

while the lowest point in the shore line of the same stage is at the southern extremity of the lake, the respective figures being 412 and 345 feet.* The departure of this shore line from a horizontal position is more than can be attributed to the attractive influence of the ice on the water of the lake. Furthermore, the shore line does not rise steadily to the north, as would have been the case had the attractive effect of the ice been the cause of the departure of the shore line from horizontality. There is no doubt that the basin of the lake has suffered deformation, the northern end rising, relative to the southern. It should be noted that the northward rise is relative only, so far as the direct evidence derived from the shore line is concerned. This evidence gives no criteria for deciding between the following propositions: 1°, the whole basin of the lake has risen, but the northern end more than the southern; 2°, the northern end has risen, while the southern has remained in the position it occupied during the life of the lake; 3°, the northern end has risen, while the southern has been depressed; 4°, the northern end has remained as it was while the lake existed, while the southern end has sunk; 5°, the whole basin has been depressed, the northern end less than the southern.

The phenomena of other parts of the glaciated territory of the continent indicate pretty clearly—1°, that the surface of the land was depressed by the weight of the ice sheet, and that as a rule the depression was greatest where the ice was thickest; and 2°, that as the ice sheet melted, the surface which it had weighed down recovered from its depression, rising most where it had been most depressed. Following this line of argument, it is probable that the first or the second of the above propositions represents the fact.

Elsewhere in the glaciated area of the State, positive evidence as to post-glacial changes of level are wanting.†

*Annual Report of the State Geologist of New Jersey for 1893, pages 320, 321.

†Annual Report of the State Geologist for 1893, pages 208-210.

SECTION V.

THE BEACON HILL FORMATION.*

The Beacon Hill formation does not belong to the Pleistocene period of geological history, but it so closely concerns the later formations of central and southern Jersey, that the study of the latter has necessitated the study of the former.

The general stratigraphic relations of this formation were set forth in the Annual Report for 1893.† These relations are still further exhibited in the accompanying diagrams, Figures 1 and 2, Plate III., where the formation is seen to be unconformable upon the Raritan clay and the Middle marl. Farther south it overlies the Lime sand and Upper marl, so that its unconformity upon the Cretaceous is not open to question.

South of the Triassic area, its dip appears to be essentially the same as that of the Cretaceous beds. The floor on which it was deposited seems to have been nearly plane, though evidence is not wanting that it had here and there some relief. This is indicated rather by the data from certain deep borings in the material of the formation, than by contacts actually seen. The surface on which it rests has a gentle slope to the southeast, the direction in which all post-Triassic formations dip. In addition to this general slope, there seems to be also a southwesterly slope in the western part of the State and an easterly slope in the eastern part. The axis between these slopes has a general southwesterly course from the Mount Pleasant hills. These subordinate slopes are indicated by the following facts. In the Mount Pleasant hills the base of the formation has an altitude of about 360 feet; at Pine hill, near Perrineville, fifteen miles to the southwest, about 270 feet; at Arney's mount, twenty-two miles farther southwest, about 120 to 150 feet; at the mouth of Pensauken creek, about eighteen miles west of south of Arney's mount, about 30 feet. These figures demonstrate the slope to the southwest along this line. The decline of the base of the formation northeast of the Mount Pleasant hills is shown by a comparison of the altitude of its base on

*Mr. Knapp's work has furnished many of the facts embodied in this and the following sections.

† Pages 39-52.

the Mount Pleasant hills (360 feet), and at the east end of the Navesink highlands, where it is about 180 feet above sea-level. The single remnant of the formation thus far identified on Staten Island—on the bluff between New Dorp and Garretson's—has an altitude of 170 to 180 feet.

The remnants of the formation farther north (the sand hills north of Monmouth Junction), are somewhat lower than those in the Mount Pleasant hills, showing that the base of the formation does not continue to rise northwest of the latter hills.

It would thus appear that if the base on which the formation was deposited was originally plane, or nearly so, it has undergone deformation since that time. The relations of the isolated portions of the formation to each other, and to the continuous area farther south, are such as to indicate that deformation has increased the dip of the formation south of the Mount Pleasant hills, and that the uplift was greatest in their vicinity. It is probable that a belt north or northwest of the Navesink-Mount Pleasant-Clarksburg belt, including the Sand hills region, suffered relative depression at the same time.

As it now exists, the formation thickens to the southeast. It is not known how far this is the result of the greater erosion to the north, incident upon the greater altitude of the formation in that region; but it is probable that the formation was thicker to the south at the outset, and that it has also suffered less erosion. It is now essentially continuous, though often concealed by later formations, south and east of a line drawn from Asbury Park on the northeast via the Hominy hills (five miles north of Farmingdale), Charleston Springs (eight miles south of Englishtown), Prospertown, Wrightstown, Clementon and Pitman Grove, to Alloway.

The edge of the continuous body of the Beacon Hill formation is usually marked by a distinct and more or less abrupt rise of surface, as seen from the northwest. The edge of the continuous body of the formation lies a little to the northwest of the above line, where high land runs northwest of it, and to the southeast, where low land stretches in that direction.

Constitution.—Something was said concerning the constitution of this formation in the last annual report.* Little will here be added concerning this point. The formation is pre-eminently siliceous, being composed mainly of quartzose sand and gravel. On the whole, it is

* Pages 41-45.

true that its lower part is more sandy than the upper, while the latter carries more gravel, but to this general statement there are many exceptions.

The constitution of the formation changes somewhat from north to south. So far as the sand is concerned, it is coarser to the north, where it is often coarse grit and becomes finer in the opposite direction. To the south, where it is fine, it often assumes a phase which has been described as "fluffy." As the adjective suggests, it is not compact, but is in a physical condition which suggests sponginess or ashiness, so far as sand can. This phase of the sand is always fine, though it sometimes carries a few small pebbles of quartz, and is often interbedded with layers of coarse, gritty sand. It is often delicately streaked or mottled with pale shades of brown, or yellow or salmon. The mottlings are more or less irregular, but are usually elongate in the direction of the bedding planes. They are as delicate in size, shape and arrangement as in color. In exceptional localities the sand is so fine as to approach a loam, and may then stand in vertical faces after the fashion of loess.

The fine sand may be seen to advantage at the west end of Arney's mount (pit), in the railway cuts southeast of Clementon, in the 181-foot hill five miles southeast of Haddonfield, a mile northwest of Prosser's Mills (five miles northeast of Glassboro), and at the south end of the lake at Millville, in the bluff faces. It is also exposed at scores and hundreds of other places in road and railway cuts. The glass sand in the vicinity of South Vineland doubtless belongs here. The fluffy phase of the sand has nowhere been seen along the more northerly outcrop of the formation.

The fluffy sand is frequently associated with tenacious clay, which has a yellowish or pinkish color, often grading toward salmon. The clay sometimes occurs in the form of beds one to four feet thick, but more commonly as laminæ, a fraction of an inch in thickness. It frequently contains small pebbles of quartz, which range in size up to half an inch. This clay is known at many points from Asbury Park to Millville.

The fluffy sand, as well as some of the sand which does not possess the quality denoted by this adjective, often has a peculiar pinkish color, which has been seen in none of the later formations of the State. In some places this color is especially concentrated in the

cemented or semi-cemented portions, where it sometimes assumes a purplish cast.

Another phase of the Beacon Hill sand is hardly less characteristic, though less easily defined. It is coarse, or at least contains many coarse grains. It at first seems much more coherent than the fluffy sand, and layers of it associated with the latter are likely to stand out in exposed faces almost as if indurated. But of induration there is really nothing. If a piece of it be detached, it can hardly be handled and preserve its integrity; but instead of crumbling into its constituent grains, it breaks into a number of smaller pieces. Each of these behaves in a similar manner. That is, while there is some small measure of cohesion, the sand, especially when wet, is excessively brittle. It is "wet short." This phase of the sand very commonly carries pebbles of quartz of small size. It may be well seen in the railway cut at Fountain Green, four miles northeast of Pemberton, and in the road cut two or three miles west of Asbury Park.

One of the most characteristic features of the Beacon Hill sand as a whole, is its cleanness. Locally it contains a notable amount of white mica, in very tiny scales. This is perhaps one of the causes of its fluffiness.

The gravelly portion of the formation seems not only to be better developed at high elevations than at low, but to be more conspicuous the more isolated the elevations. The isolation is due to the gravel rather than the gravel to the isolation. The gravel is too coarse to be easily handled by surface drainage, and is so porous as to allow water to sink through it readily. It therefore serves as a protection to the hill on which it rests. It creeps down the slopes more or less, and thus protects their upper slopes as well as their tops. Like the sand, the gravel grows finer to the southward. The coarse material and the fine are occasionally mixed, large pebbles now and then occurring in the fine sand.

In the regions where only isolated remnants of the formation remain, the gravel consists of something like sixty-five per cent. of quartz, thirty per cent. of chert and five per cent. of sandstone. Where the quartz has been exposed to surface weathering, some of it is commonly etched into columnar forms which, in a further state of weathering, break up into splinters. Such quartz may well have come from the vein material of the Hudson River sandstone in the northern part of the State. The chert is often fossiliferous, and is

often so far decomposed as to have the texture of chalk. The proportion of quartz increases to the southward. The gravel is as notable for what it does not contain as for what it does. Granite, gneiss, trap, shale of all sorts and Triassic sandstone are conspicuous by their absence.

The question is still an open one whether the upper and more gravelly part of the formation is separable from the lower and more sandy part. Nothing has yet been seen which makes the subdivision necessary, but various things have been seen which would not be inconsistent with such division. It is certain, on the other hand, that gravel ranges through the entire thickness of the formation, as it is often present in small quantity at the very base of the formation, where it comes in contact with the marl. This has been noted at many points in Salem and Gloucester counties.

The formation is frequently cemented by iron oxide to such an extent as to become important as a source of building stone. Cementation is most prominent at the contact of the coarser and finer layers. The sand immediately beneath a gravel bed is especially likely to be indurated. The cemented portions are therefore generally sandstone, instead of conglomerate, though conglomerate layers are by no means unknown.

While iron oxide is the commoner cement, the sand is here and there bound together by silica instead. Fragments, and even considerable masses of sandstone, or even of vitreous quartzite, of this type may be seen on the crest of the little hill (255 feet) a mile northwest of Clarksburg, and at the west end of the marsh along the creek a quarter of a mile farther north. Occasional pieces of this material are met with in the later formations.

In the vicinity of Woodstown and Alloway the Beacon Hill formation is seen to overlie the "Astringent" clay (Cook), and to underlie the Pensauken. It is known to contain fossils at a point near Millville, and at another near Mullica Hill. At the latter place, the fossils are found in a layer of clay which lies between beds of fluffy sand. The sandstone near Bridgeton, which contains fossil leaves, is almost certainly a part of this formation.

Figures 1, 2 and 3, Plate III., indicate better than description can, the amount of erosion which the Beacon Hill formation suffered before the deposition of the Pensauken. There is some indication that the pre-Pensauken erosion of the formation is to be referred to

two stages more or less distinct, the one proceeding to a certain stage while the land stood at a given level, while the other was carried on after it had suffered further uplift. Such evidence as is in possession concerning this point is drawn from many bench-like terraces about the hills of the Clarksburg-Perrineville region.

It seems certain that the formation which is here described under the name of Beacon Hill, is to be correlated with formations which Professor Clark has classed as Miocene.* It is said to have much physical resemblance to the Chesapeake formation farther south. Independent of the correlation of the Beacon Hill formation with Dr. Clark's Miocene, there is evidence that it is to be so referred, as will appear later. The name Beacon Hill was adopted in the last annual because, at that time, its Miocene reference was still an open question. Now that the formation is better known through a wider range of territory, it is probable that a better name may be found. For the present, however, the name already used is retained.

The formation is known to occur at Media, Pennsylvania, where it may be seen at the bottom of the sand pit in the northeastern part of the city, near the reservoir. Only the fine white sand, beneath the coarse, more or less arkose and highly colored sand, belongs here.

* Annual Report, 1892, page 210.

SECTION VI.

THE PENSAUKEN FORMATION.

A broad, shallow topographic trough crosses the State in a northeast-southwest direction, from the Delaware river to Raritan bay. The southwest end of this trough lies between Trenton and Burlington, and the northeast end between New Brunswick and Matawan. Its width varies from ten or eleven to sixteen miles, being widest to the southwest. Its axis occupies the belt along which the lower members of the Cretaceous series outcrop. It appears to have been produced chiefly or wholly by erosion after the Beacon Hill period. Triassic shale forms the northwestern side of the trough, while the Lower marl and the Red sand formations occupy the southeast slopes. The general relations of the trough in cross-section are shown in Figure 1, Plate III. Within this broad trough, the surface of which nowhere rises much above 150 feet A. T., the extra-glacial formations of the State, younger than the Beacon Hill, are well developed.

Within this trough the surface formations are separable into at least three divisions, which were recognized in the last report.* The oldest of these formations is the Pensauken, named from a locality where it is typically developed, well exposed and easily accessible, viz., the mouth of the Pensauken creek just below Palmyra. The second formation is designated the Jamesburg formation, the name being derived from a locality where it is well exposed and likewise easily accessible. This formation forms the subject of the next section. This third formation was early named the Trenton gravel. It has long been recognized that the Trenton gravel is of late glacial age, being the deposit made by the glacial drainage which coursed through the Delaware valley at the time the ice was developing the terminal moraine near Belvidere.

In the southwestern part of the State, along the lower course of the Delaware, the Trenton gravels and sands are covered by stratified loam, grading from clay to sand, which, as its character proves, was deposited after the Delaware river had ceased to bring down glacial detritus, or at least after such detritus failed to reach the latitude of

*Annual Report of the State Geologist, 1893, pages 52–65.

Burlington. This loam corresponds with the surface formation about the eastern and southern borders of the State, reaching the altitudes of forty to forty-five feet. It is probable that it should be regarded as a fourth formation, though the measure of its distinctness has not been definitely fixed.

As stated in the last report, the basis for the subdivision of these surface formations is found in their topographical, geographical and stratigraphical relations, as well as in their physical and lithological constitution.

The Pensauken formation was defined in the Annual Report for 1893.* Since that time considerable study has been devoted to the areas where it is developed, and a somewhat fuller statement of its characteristics and relations is now possible.

Topographical relations.—Within the Bordentown-Raritan Bay belt, the Pensauken formation consists of beds of sand and gravel which occupy chiefly the divides between the streams. Where erosion has proceeded so far that the ridges between the valleys have been much dissected, the Pensauken formation occurs in isolated patches only, on the higher hills which are the remnants of dissected ridges. Where the stream valleys are shallow, and have no tributaries, or only very shallow ones, the formation is continuous over larger areas.

In any given locality the base of the Pensauken is at a nearly-constant level. This level varies in different parts of the trough. In the vicinity of Trenton it is about 80 feet; near Bordentown, 90 to 100 feet; south of Burlington, 60 to 70 feet. The altitude of the surface on which the formation rests rises slightly to the east, being 110 to 120 feet at Hightstown and Old Bridge. Still farther northeast it declines again, having an elevation of 90 to 100 feet in the vicinity of South Amboy. Toward the southeastern margin of the trough, the altitude of the base at different points is slightly different; thus at Kinkora the bottom of the formation has an altitude of about 85 feet; at Bustletown, 75 feet; at Georgetown, 100 to 110 feet; at Jobstown, 100 feet; near Arneytown, 130 to 135 feet; near Disbrow's hill, about 170 feet, and near Englishtown, about 180 feet. The last two localities are near the border of the trough.

The surface on which the formation was deposited is therefore a little higher near the center of the trough than at either end. The variations in altitude may have existed when the formation was laid

* Pages 52–60.

down, though they seem to be due, in part at least, to subsequent deformation. The differences in altitude along the axis of the trough are not sufficiently great to interfere with the truth of the general statement that the surface on which the Pensauken formation was deposited was a peneplain.

To this general statement there are a few well-marked exceptions. One of the most striking is at Kingston, where the base of the Pensauken has an elevation of no more than 40 feet A. T. The relations are such as to suggest that at the time of its deposition there was here a well-marked valley, considerably below the general level of the surface on which the formation lies.

Geographical distribution.—Considered with reference to its geographical distribution within the general area specified, the Pensauken formation is found to be best developed along the axis of the trough, or a little northwest of it. Along this line it consists of more extensive and deeper beds than elsewhere. Along the northwest margin of the trough, it occurs as patches only, resting on the shale slope of the trough, or rarely, as at Kingston, filling valleys. Toward the southeastern margin of the trough, as the marl series is approached, and as the surface rises slightly, the formation is represented by isolated patches, smaller and smaller in extent, capping the higher divides and occasional isolated hills.

It may here be noted that isolated patches of the Pensauken occur outside the trough to the northwest, while both isolated patches and considerable areas are found outside the trough to the southeast. On the north side, remnants occur at several points as follows: 1°, about five miles north of Monmouth Junction, and one to three miles northeast of Griggstown, several small areas, at elevations ranging from 130 to 150 feet; 2°, just west of Rocky Hill at an elevation of about 150 feet; 3°, a mile west of Harlingen, at elevations ranging from 120 to 150 feet; 4°, just west of Flagtown, near Neshanic station, at an elevation of about 140 feet; and 5°, north of Raritan at a slightly higher level.

On the south side of the trough the Pensauken has a wide distribution. Near the Delaware river there is a belt where it is mainly wanting. Farther east there is a belt running through Blackwood, Mullica Hill and Woodstown, where it occurs in isolated patches, capping the higher hills. Still farther east it becomes continuous.

In any limited area the base of the formation has a tolerably con-

stant level, but this level changes from point to point. In general it declines to the west and south, and rather more rapidly in the former direction than in the latter. At Fish House, on the Delaware river, the upper surface of the formation can hardly be higher than 15 feet A. T. This is the lowest position which the formation is known to occupy. It here lies beneath the Fish House clays, the age of which has been in dispute. It is certain that they are post-Pensauken. In the vicinity of Woodstown and Mullica Hill, the region of isolated patches of the formation, its base has an altitude of 110 to 130 feet, but at Riddleton, five miles south of Woodstown, it has declined to 75 feet. Two and one-half miles southwest of Marlton, and nine miles southeast of Fish House its base is at 150. To the southeast it becomes continuous, or essentially so, along a line which corresponds approximately with that already defined,* as marking the northwest limit of the continuous body of the Beacon Hill formation. The eastward extension of the formation has not been determined, but it is reasonably certain that it covers most of the State southeast of the line referred to. It is wanting, however, on the low lands bordering the shore.

From its topographical and geographical relations, it would seem that the Pensauken formation once covered nearly the whole of the southern portion of the State, lapping up far on to the Triassic area, and in places even reaching the crystalline schist highlands. It seems to have been accumulated on a plain or peneplain, in which there were a few well-marked valleys.

The formation, together with the plain on which it was deposited, appears to have been somewhat deformed since its deposition. The elevation seems to have been greatest along an axis corresponding essentially with that already noted in connection with the Beacon Hill formation (page 99).

Subdivisions of the formation.—Where the Pensauken is best developed, along the central line of the trough, it consists of two more or less distinct members. The lower of these is composed principally of arkose loamy sand, and the upper more largely of gravel. Both parts are stratified, and grade into each other through alternating beds of sand and gravel. The basal or sand member is more evenly stratified than the upper. In the former, the stratification planes are often nearly horizontal, and the layers thin. Cross-stratification, however,

*See *ante*, page 100.

is often well developed, and after a fashion which is rather peculiar to this formation. The gravel member is more irregularly stratified, and the gravel beds are frequently lens-shaped, as seen in cross-section. They are frequently cross-stratified, and the planes of dip are often high.

Constitution of the formation.—This formation has among its constituents all sorts of materials which the Miocene beds contain, including Miocene conglomerate. It also contains materials from the Cretaceous beds which underlie the Miocene, and which had been exposed by the erosion which followed the deposition of the Miocene and which preceded the deposition of the Pensauken. The Pensauken also contains fragments of shale and sandstone from the Triassic formation, as well as fragments of trap, gabbro, gneiss, granite, chert, Medina and Oneida sandstone and conglomerate, and probably fragments from the Green Pond mountain conglomerate. This last element is in some doubt, since small fragments of this conglomerate are not always to be distinguished with certainty from bits of Medina and Oneida. Thus it will be seen that the Pensauken formation is lithologically very much more heterogeneous than the Miocene.

Stated in more detail, the basal or sandy member of the Pensauken consists of coarse, angular or sub-angular sand. The grains are often an eighth of an inch in diameter. Individually, they are generally transparent internally, but are stained by iron oxide on the outside. The result of this staining is to give the formation as a whole a yellow to orange color, sometimes grading towards reddish-brown.

Wherever exposures of any considerable depth are found, there may be seen frequently small bits of decomposed feldspathic material. They do not occur within three or four feet of the surface, their absence being due apparently to the effects of weathering. These bits of kaolin are a quarter to a half inch in diameter. They can hardly be said to be abundant, yet in the area under consideration they are almost never absent. Associated with the sand, often coating its grains and sometimes so abundant as to make a considerable part of the matrix, there is a white or pale yellow, kaolin-like substance the real nature of which has not been determined; where this material is plentiful, it gives to the whole a sort of arkose appearance. Together with the iron oxide which coats the sand grains, it gives to the formation a considerable degree of compactness in many places, and enables it to stand in vertical or even hanging faces, ten feet or more in

height. Exposed faces often harden to such an extent as to be difficult to cut or break through.

At some points the Pensauken formation contains a small amount of marl. This may be seen at Jamesburg, and at numerous points farther south as the outcrop of the marl series is approached. Nevertheless, when the formation is considered as a whole, the presence of marl grains is the exception rather than the rule.

The basal or arkose sand member of the Pensauken formation is present throughout the central part of the trough from South Amboy to the Delaware. It is best developed somewhat northwest of the axis. Still farther to the northwest, outside the trough, where remnants only of the Pensauken are found, this member is not conspicuous. Along the southeast side of the trough, the arkose sand is absent, being replaced by sandy material which appears to have been derived chiefly from the commingling of materials from the various members of the Cretaceous and Miocene series. Throughout its entire extent, the arkose sand member of the Pensauken maintains essentially constant characteristics.

South of the Raritan bay-Bordentown belt, the formation is less clearly divisible into the two members noted above. The gravel and the coarse sand are more uniformly commingled, though it still remains true, that the more gravelly portion of the formation is likely to be above the more sandy part. In the southern part of the State, too, the color is more likely to be red or reddish than farther north. Occasionally the color is not high. When this is true there is little loam associated with the coarse sand. This phase of the formation may be seen near Riddleton and at Big Mannington hill, south of Woodstown.

The upper or gravel member of the formation is heterogeneous, both physically and lithologically. In diameter, its constituents range from a half inch to four feet, though bowlders of large size are rare, and bowlders four feet in diameter especially so. In spite of the great range in size, there is usually a standard size for any given locality to which most of the material conforms. Thus in one place a half to three-quarters of the pebbles may fall between the diameters of one and two inches. There are likely to be a few cobbles three or four or five inches in diameter associated with the smaller pebbles, and perhaps an occasional bowlder.

To this general characteristic there are a few notable exceptions.

In one case, namely, at Kingston, the material ranges in size from a foot in diameter down to sand, and no one size can be said to be dominant. Where bowlders or large masses of rock occur they are usually not well worn, their forms often being those of slabs rather than those of bowlders proper.

The lithological range of the material is wide. The following types of rock occur, arranged approximately in the order of their abundance:

1. *Quartz* is always present, generally in the form of pebbles one to two inches in diameter, rarely as cobbles and very rarely as small bowlders. Much of the quartz appears to be such as might have been derived from quartz veins in crystalline rock. Some of the quartz has a distinctly columnar structure such as characterizes the quartz veins of the Hudson River formation in the northern part of the State.

2. *Chert* is always present. In size its fragments correspond in a general way with those of quartz, though bowlders are wanting. The cherts are often soft from decay.

3. Water-worn bits of *ironstone* are almost always present along the Raritan bay-Bordentown belt, but almost always absent south of that belt. They are generally small, thin, chip-like fragments, an eighth to a half inch thick and a half inch to six inches broad, but without sharp corners and angles. Their proportion varies greatly. Locally they are more abundant than any other material, but ordinarily they do not constitute more than one or two per cent. of the whole.

4. Bits of *crystalline rock* of such types as occur in northern New Jersey are always present within certain geographical limits. Here are included bits of granite, gneiss, schist, syenite, gabbro, trap, etc. These crystalline materials range in size from a half inch to four feet in diameter, though pieces more than four or five inches across are rare. The crystalline material is much more abundant north of the axis of the trough, and disappears altogether along its southwestern margin. Crystalline material of another type, derived apparently from the Philadelphia gneiss, occurs in the formation in the southwestern part of the State.

5. *Red shale* and red and grey sandstone derived from the Triassic formation to the north are always present where material derived from the crystalline rock formation is found. This class of material in-

cludes pieces of arkose conglomerate such as occurs at many points in the Triassic formation of western New Jersey.

The constituents of this class range in size from minute bits to pieces three feet in diameter, the large pieces being generally unworn. These Triassic fragments are found as far to the south as Tuckahoe, and have been noticed in the vicinity of Millville, Hammonton, Cohansie, Alloway, Woodstown, Marlton and Fish House. They constitute one of the most characteristic marks of the formation.

The remaining constituents are of little importance quantitatively, though otherwise significant. Their distribution is for the most part more local than that of the preceding types.

6. A type of sandstone and quartzite distinguishable from the following is widely distributed, though usually not in great quantity. It is especially present in the form of bowlders, varying in texture from loose sandstone to hard quartzite, and is often conglomeratic. These bowlders correspond in kind with those which are common in the extra-morainic glacial drift. They are the type of bowlders most common over all the extra-glacial region of New Jersey. So far as lithological character is concerned, they might well be derived from the Paleozoic (Cambrian) sandstone formations of the northern part of the State.

7. The *Oneida* conglomerate and sandstone and quartzite are generally represented by a small amount of material, in the form of cobbles.

8. Pebbles and cobbles of red sandstone are found in small numbers, which may well have come from the *Medina* formation, though their identification is perhaps not beyond question.

9. A peculiar sort of sandstone is frequently found in pieces of some size, which has peculiarities which seem to distinguish it from the other materials, although it cannot be referred to any definite formation. Their peculiarity is in their form, which is columnar. They frequently seem to be sections of five or six-sided prisms, the prism faces being often well defined, and the ends sharp. The bedding planes of the sandstone are often distinctly seen in the columns, and make an angle of seventy to ninety degrees with the columnar faces. The texture is firm, and varies from medium to fine grain. The sandstone is light brown in color, often somewhat resembling the sandstone derived from the Beacon Hill formation.

10. Cobbles and small bowlders are frequently found which may be referable to the Green Pond mountain formation. These are

more abundant in the region south of New Brunswick than elsewhere. Bowlders from the Green Pond mountain range are by no means rare in the Jamesburg formation in this vicinity. They are not to be mistaken for those in the Pensauken.

The composition of the Pensauken is such that it makes good road material at many points. This is especially true where its matrix is loamy or clayey, and where its content of ironstone, or of decomposed rock bits, such as chert, granite, etc., is large. Where the matrix is sand, and where the gravelly constituents named are absent or nearly so, the material is too loose to pack readily in the roadbed.

Geographical variability of physical character.—The material of the gravel member varies in size from place to place. There are variations which are only local, and variations which are more than local. A line drawn approximately parallel to the outcropping edge of the Lower marl, and about three miles northwest of it, would mark the southern limit of the area within the Raritan bay-Bordentown belt, where materials having a diameter of more than one foot are common. Southeast of this line, also, the average size of the material is much less than that to the northwest. South of this belt bowlders of considerable size occur, even to the limits of the formation, as at Millville. Northwest of this line, bowlders are especially abundant in three localities. These are as follows: 1°, east of Trenton, within five or six miles of the Delaware river; 2°, south of the gap in Rocky Hill where the Millstone crosses it; 3°, south of Raritan bay, and along the valley of Lawrence brook.

Geographical variability of lithological characters.—Geographical variations in the lithological character of the material correspond in a general way with the geographical variations in its physical character. The minor constituents of the gravel are the more variable in their distribution, while the more abundant materials are more widespread. Thus, while quartz is always abundant, the crystalline material of northern origin is much more abundant along the axis of the Raritan bay (Bordentown depression), and northwest of it, than farther to the south. Southeast of the axis of the depression, but still within its limits, as the outcropping edge of the marl series is approached, the lithological character of the formation changes to such an extent that three miles or so from the marl series, the granitic or gneissic and Triassic materials are essentially wanting, and there remain only quartz, chert, ironstone, and a small but variable amount of sandstone,

as constituents of the gravel. Farther south, as already noted, the Philadelphia gneiss made its contribution, and it is suspected that the Triassic material of the southern part of the formation may also have come from Pennsylvania.

Within the northwestern part of the trough there are three localities where the crystalline materials are more abundant than elsewhere. These three localities are the localities where the bowlders are most abundant, viz., 1°, near the Delaware river; 2°, south of the gap in Rocky Hill through which the Millstone passes; and 3°, the region of Raritan bay.

Decomposition.—Throughout the whole area of the Pensauken, the crystalline material is largely decomposed, and in most instances thoroughly so. It is nothing rare to find granitic bowlders two feet in diameter so thoroughly decomposed, even to their centers, that a trowel can be as easily thrust into them as into a bed of clay. The trap and gabbro bowlders are decomposed in like manner, but seldom so completely. Large masses of these materials generally have a core of firm rock. The Triassic shale, sandstone and conglomerate are usually so thoroughly decomposed that it is difficult to remove a piece of any size from a section where it occurs without having it fall to pieces.

Source of the material.—The lithological character of the material gives a clue as to its origin. There is but one known source whence the Triassic material could have come, namely, the Triassic formation to the northwest. Much of the gneissic material in the formation near Trenton appears to have come from the Trenton gneiss, and farther south from the Philadelphia gneiss. The other crystalline materials seem to have come from regions farther north. The trap doubtless came from the trap formations of the State. Certain gabbro bowlders have been found, the source of which is not known. No rock formation is known in the State which would have given origin to them. At South Amboy, bowlders of crystalline schist, full of garnets, have been found, the source of which is not known. The Medina, Oneida and Green Pond mountain materials speak for themselves. There can be no doubt that they came from the corresponding formations in the northern part of the State or beyond. The quartz and the chert may have been derived originally from the crystalline schist, and limestone formations of the northern part of the State, or from adjacent areas in New York and Pennsylvania;

but as constituents of the Pensauken, they were probably derived very largely from the Beacon Hill formation, which had been wholly removed from the trough under consideration before the deposition of the Pensauken. In the southern part of the State the material of the formation came largely from the Cretaceous and Miocene formations of that region.

Method of origin.—From the structure of the Pensauken, a subaqueous origin is inferred, especially when the nature of the stratification is considered. The distribution of the gravel constituents points to the conclusion that in the northern part of the area under consideration, they were largely contributed by the Delaware river, by the river which then flowed southward through the gap at Rocky Hill (the Raritan), and along a third line of supply which may well have been the Hudson river, or the stream which came down the west side of the Palisade ridge.

While the Pensauken was being deposited, the State seems to have been submerged to such an extent that the low belt between the Delaware at Bordentown, and Raritan bay, was converted into a sound. At the same time Delaware bay was greatly enlarged, reaching to Trenton and beyond. Into this bay the Delaware river is believed to have emptied just above Trenton, and the materials which it brought down were spread as far as the waves and currents could carry them. To this bay, also, the Schuylkill doubtless made important contributions.

With reference to the second line of supply, it may be said that there is the best of reason for believing that the Raritan river formerly flowed southward from Somerville up the present course of the Millstone, through the gorge at Rocky Hill, to the junction of the Millstone with Stony brook. Thence the Raritan seems to have followed up the present valley of Stony brook to Port Mercer, thence across the low divide to Shipetaukin creek, thence down that valley to the Assanpink, and thence to the Delaware. During the Pensauken submergence, the Raritan emptied into this sound at Kingston. From that point the material which it brought down was spread in all directions, giving rise to an abundance of arkose and crystalline material in this vicinity.

The third source of supply is believed to have come down the Hudson or the Hackensack valley, and to have been deposited south of Newark bay. The material from this source has been less well

studied, but it is clear that the materials contributed along this line were somewhat unlike those contributed by the other two streams.

The presence of bowlders, even large ones, in the Pensauken formation, as far south as the limit of the State, is suggestive of unusual conditions of deposition. The fact that some of them, especially those in the eastern part of the State, seem to have come from some source far beyond the northern border of the State, is also suggestive. Not less significant than the great size of some bowlders, and the great distance whence others have come, is the physical character of certain others. Masses or slabs of red Triassic shale a foot and more in diameter occur thirty, forty and fifty miles from their nearest possible source. It is not of so much significance that these masses are soft now, as that they were almost surely soft at the time they were deposited as constituents of this formation. This is believed to be true from the fact that very much of the Triassic shale seems never to have been so hard but that, when wet, it could be readily cut by a knife. Many of the Triassic slabs in the Pensauken belong to just that phase of the Trias which seems never to have been hard. When the distance which they have been carried is remembered, it seems almost incredible that such masses of shale could have been carried from their parent formation by water alone. Even if this were possible, it is difficult to see how they could have journeyed so far and have still preserved this angular form. It is not easy to see how even the small bits of shale could have been transferred by water the necessary distances, along with the hard quartz pebbles with which they are associated. It would seem that, in the process of transportation, they would speedily have been ground to powder.

The foregoing considerations seem to point to floating ice as a co-operating agency in the production of the formation. Whether it was river ice, or icebergs is still an open question. It should be noted, however, that no striated bowlder or stone has been found in the formation.

Thickness.—In thickness, the Pensauken varies from nothing to fifty feet. So great depths as fifty feet are known in but two places, and in both these the material appears to fill valleys somewhat below the general level of the peneplain on which the Pensauken was deposited. No figure can be given which represents very accurately the average thickness of the formation. Depths of ten to twenty feet are common, and depths of thirty feet can hardly be said to be rare.

It is to be remembered that the formation, as now known, consists only of remnants, but these remnants are often in such positions and relations as to make it probable that their depth represents approximately the original thickness of the deposit at the points where they occur. In the broad trough, the formation seems to be rather thicker along the axis than toward the margins.

Age of the Pensauken.—There can no longer be any doubt that the Pensauken is the equivalent of the Lafayette formation of the south. This conclusion was reached tentatively more than a year since. Recently, Mr. McGee was kind enough to spend several days in the study of the formation at various points, from Millville to Kingston, and at the close of his study expressed his conviction, without qualification or reservation, that the Pensauken and the Lafayette are one.

If the ice which co-operated with water in the deposition of the Pensauken was berg ice—emanating from glaciers—it is believed that it belonged to a glacial epoch antedating any which has heretofore been recognized in North America.

Exposures.—The following is a list of some of the good exposures of the Pensauken; they show different phases of the formation: 1°, the roadside pits south of Rancocas, where the base of the formation is much below its usual level; 2°, a pit two and one-half miles south of Burlington, on the south side of the ninety-foot hill; 3°, the gravel pit in the 106-foot hill, one and one-half miles due east of Deacon's station (one of the best sections); 4°, the gravel pit three-quarters of a mile west of north of Jacksonville, in the 103-foot hill; 5°, a gravel pit three quarters of a mile north of east of Bustleton church; 6°, a gravel pit one-half mile southwest of Bustleton church; 7°, a gravel pit two miles west of Columbus, on the Columbus-Burlington road; 8°, a gravel pit at the corner of the road which turns east, one quarter of a mile north of the church, at Mansfield; 9°, a gravel pit south side of the Mount Holly pike, one mile northeast of Jobstown; 10°, a gravel pit at the corner of the roads one-quarter of a mile south of Georgetown; 11°, a gravel pit one and three-quarters miles northwest of Chesterfield; 12°, east of Bordentown, on the north side of the Bordentown-Chesterfield road, one-half a mile northeast of the reservoir; 13°, a gravel pit above the clay pit one-half mile west of Crosswicks—west bank of creek; 14°, a gravel pit three-quarters of a mile southeast of Davis station; 15°, a gravel pit three-quarters of a mile southeast of New Sharon; 16°, a gravel pit just northeast of Newtown station; 17°,

a gravel pit one-quarter of a mile south of the corner near the church, at White Horse; 18°, gravel pits one-half to three-quarters of a mile northwest of the above corner, on the road to Trenton; 19°, a gravel pit just west of the meeting of five roads near Mercerville; 20°, a gravel pit one-half mile northeast of Lawrence station, at roadside, forty rods south of the corner; 21°, gravel pits one and one-half miles southeast of Lawrence station; 22°, a gravel pit one-quarter of a mile southwest of the above station; 23°, a gravel pit three-quarters of a mile north of Half Acre; 24°, a gravel pit, near the top of the hill, one and one-half miles northwest of Englishtown; 25°, the railway cut one-half mile southwest of Jamesburg; 26°, a gravel pit three-quarters of a mile south of Jamesburg station; 27°, gravel pits and quarry one-half mile north of the canal lock at Kingston; 28°, a gravel pit one and three-quarters to two miles northwest of Spotswood, east side of the road; 29°, the railway cut at Hardenburgh Corners; 30°, a road cut in the hillside, above the hotel, at Old Bridge; 31°, a gravel pit one and one-half miles northwest of Old Bridge, and just east of the Middlesex driving park; 32°, the railway cut of the Raritan and South Amboy railway southeast of New Brunswick, near Lawrence brook; 33°, at very numerous points about South Amboy, in railway cuts and gravel pits, especially in the pit in the 147-foot hill; 34°, a gravel pit at Bonhamtown; 35°, a sand pit one mile north of Raritan.

South of the belt in which the foregoing exposures are situated, the formation may be well seen at the following points, at most of which there are pits where the material is dug for road purposes: 36°, the 181-foot hill two and one-half miles southwest of Marlton; 37°, two and one-half miles northwest of Berlin; 38°, a railway cut and pit just north of Pitman Grove; 39°, one mile northeast of Woodstown; 40°, two miles south-southwest of Alloway; 41°, a half mile south of Daretown; 42°, at Cohansey; 43°, at two pits one and one-half and two and one-half miles, respectively, south of Millville, on the west side of the river; 44°, at the railway cuts a mile and a half southwest of Hammonton (Miocene at bottom); 45°, at the railway cut near New Germany (Miocene at bottom); and 46°, at a railway cut and pit three miles or so northwest of Tuckahoe.

This by no means exhausts the list of exposures. The fact that so many of them are gravel pits tells its own story as to the value of the formation, for purposes of road construction. The more sandy part of the formation is in demand in foundries.

SECTION VII.

THE JAMESBURG FORMATION.

The Jamesburg formation, which next succeeds the Pensauken, is disposed as a sort of mantle over all the formations of greater age in central and probably in southern Jersey. South of the north line of the Cretaceous beds, only a few of the higher points appear to be free from it, except where its absence is due to subsequent erosion. It is altogether possible that the deposits which have been grouped under this name should be subdivided. At any rate, both the formation and its history are complex. Although studied independently, and its relations fixed without reference to work which had been done elsewhere, there can no longer be any doubt that the Jamesburg of New Jersey corresponds to the Columbia of the south as defined by McGee. Not only this, but it is also clear that there have been referred to the Jamesburg, deposits which correspond in a general way with the "high-level" and "low-level" Columbia. The relation of these two subdivisions to each other has not yet been fixed with certainty, but will receive attention in the immediate future. It has not yet been found possible to draw a sharp line of division between the two phases, but there is some reason for believing that this may be done. The areas which promise the best results in this line have not yet been studied in detail with this in mind. From a slight knowledge of the formation in the south, it is believed that the Columbia of that region has been made to include even more than has been included under the name Jamesburg in New Jersey.

Distribution.—The Jamesburg formation occurs throughout most of the trough-like depression referred to in connection with the Pensauken formation, and extending from Trenton and Burlington on the Delaware, to Raritan bay. It not only covers the bottom of the trough, but laps up onto its sides both to the northwest and to the southeast, and apparently somewhat higher in the latter direction than in the former. Although most of the southern part of the State has not been studied in great detail, it is believed that the Jamesburg is there essentially continuous, the higher hills and ridges only being above its level. North of the trough referred to, it has

little development. There are some isolated deposits up the valley of the Delaware, which may belong with the Jamesburg, but this correlation cannot be looked upon as beyond question. The geographical distribution of the Jamesburg formation is quite as wide as that of the Pensauken. Within the general area of its occurrence it is much more nearly continuous, being wanting only on surfaces which are so situated as to favor erosion.

In some places the Jamesburg formation does not appear to rise so high as the Pensauken. Thus along the northwest border of the depression referred to, the upper limit of the Jamesburg appears to be in general about 130 feet, while the Pensauken reaches a somewhat greater altitude. At one point only, near Pennington, does the Jamesburg seem to rise notably above 130 feet, and even there its identification is not beyond question. The contour marking the level referred to (130 feet) is the approximate northwest limit of the Jamesburg, from the Delaware to the moraine, though near the moraine it is covered by sand and gravel of late glacial age.

The stratigraphic relations.—The Jamesburg formation is unconformable on the eroded surface of the Pensauken and older formations. It covers the remnants of the Pensauken in many places, and in closely associated localities rests on various members of the older formations from which the Pensauken had been removed before the deposition of the Jamesburg. Apart from the broad unconformity thus suggested, there are minor irregularities of the underlying surface, which may be seen at many points. These are of various sorts and are of varying significance. Many of them denote stratigraphic unconformity, others are the result of the upturning of trees which sent their roots through the Jamesburg into the Pensauken beneath.

Constitution.—The constitution of the Jamesburg formation is as variable as that of the Pensauken, or perhaps even more so. Its character is influenced by subjacent and adjacent formations, to a large extent. Within the area where the Pensauken is well developed, the material of the Jamesburg is of such a character as to suggest that it was derived principally from the former. The most conspicuous point of difference between the two lies in the fact that the Jamesburg never contains the soft, decomposed materials of the Pensauken. The granite, gneiss, etc., which are especially characteristic of the Pensauken, are never present in the Jamesburg; neither are the soft bits of red shale, or soft pieces of decomposed chert. The action of

waves or of running water upon the Pensauken would give rise to a product very like the material of the Jamesburg. Such action would reduce the decomposed materials of the former to the condition of loam, sand, etc. In keeping with this suggestion, it is to be noted that the Jamesburg material is often much more loamy than the Pensauken, and is sometimes rather clayey. At some points it would seem that some contribution of clay-loam must have come in from some other source, if the bulk of the Jamesburg was derived from the Pensauken. Locally the Jamesburg is sandy. This is especially true where the underlying formation is Miocene sand or gravel, or an unusually sandy phase of the Pensauken. The Jamesburg is never arkose, even where the Pensauken beneath is notably so.

Along the northwest side of the trough, the Jamesburg may be said to be a gravelly loam. The loam predominates above, and the gravel is relatively more abundant below. This is shown at the brickyards about Trenton, and the same relations have been observed at many other points where exposures are less good or less accessible. It contains bowlders, along with smaller stones. The bowlders are occasionally glaciated, and those which bear the marks of ice are co-extensive with the formation, so far as it has yet been studied in detail. The bowlders are almost wholly of sandstone, such as are abundant *in the extra-morainic* glacial drift. They are much more abundant along the northwest side of the depression referred to, than farther southeast.

Along the southeast side of the trough the character of the Jamesburg changes, and changes in a significant way. The Pensauken formation was more largely removed from this region than elsewhere, before the deposition of the Jamesburg. It therefore made less contribution to the latter, while the contribution of the underlying Cretaceous and Miocene was correspondingly swollen. Thus green sand becomes much more abundant in the Jamesburg as the marl belt is approached. Its prevalent character is that of a marly loam. To the northwest the glauconitic material does not extend more than two or three miles from the line of the marl outcrop, except along the valleys coming out from the marl belt. Along these the presence of green sand extends farther from its source. The proportion of glauconite decreases with increase of distance from the marl belt.

On the south side of the depression heretofore referred to, the Jamesburg takes on a significant phase. Even on the higher lands

south of the marl outcrop it contains a considerable amount of green sand, and *that at levels considerably higher than the outcrops of the marl,* showing clearly that green sand from the marl was lifted by the depositing waters and finally dropped at levels considerably above its source. In such situations the Jamesburg is a green loam, containing at its base more or less gravel derived from the bed on which it rests. This green glauconitic phase of the Jamesburg is well shown in the railway cut at Fountain Green (top of section). It may also be seen resting on Miocene, at an elevation of 214 feet, two miles east-northeast of Cream Ridge, and at an elevation of 180 feet three miles southwest of Marlton. Its presence may be said to be rather general along the southeast side of the line of marl outcrop.

The high-level Jamesburg is often very thin. Where it rests on the Pensauken it frequently has the appearance of being but the weathered part of the latter, so that it is often very difficult to distinguish between them on lithological grounds. So true is this that study had been long in progress before the existence of the "high-level" Jamesburg over the higher areas of the Pensauken was regarded as demonstrated. The great body of facts now in possession, however, has put the existence of this phase of the formation beyond question. This statement is made with full recognition of the fact that good observers might see scores of sections of Jamesburg and Pensauken, the one over the other, without suspecting a subdivision, unless attention was especially directed to the matter. Even then it is probable that nine sections out of ten, or perhaps forty-nine out of fifty, would fail to be convincing on lithological grounds. But the tenth section or the fiftieth is conclusive, and carries the other nine or forty-nine with it.

As will be pointed out later, there is, independent of lithological considerations, sufficient reason in the topography of the region where the Jamesburg is well developed, to demonstrate the submergence of the areas where it is present, subsequent to the erosion which followed the deposition of the Pensauken. There are, therefore, two independent lines of evidence, either of which is believed to be quite sufficient for the recognition of the high-level Jamesburg as distinct from the Pensauken, and both of which, taken together, do not leave room for question. Nevertheless the nature of the evidence in most places is not of such a character as to carry conviction at sight.

The low-level Jamesburg is not less variable than the high-level. At low altitudes it commonly rests on formations older than the Pensauken, and is so far unlike them lithologically as to be distinguished as a separate formation without difficulty. As compared with the high-level portion of the formation, it seems to contain materials gathered from somewhat wider sources. This is especially true in valleys, where the nature of the formation at any given locality may be influenced by all formations which lie above it along the line of drainage.

Structure.—The Jamesburg formation is less well stratified than the Pensauken. Where exposures can be found which go below the frost line, stratification is shown more or less distinctly, even though crude and irregular. The stratification lines are often much contorted and bent upon themselves. In some cases the contortion reaches such a degree as to strongly suggest that some shoving or thrusting or kneading action has taken place. This irregularity and contortion of stratification are among the anomalous features of the formation, and for them no adequate explanation has been found.

Another point in the structure should be mentioned. The formation is composed of gravel, sand and loam, and the gravel is rather more abundant below than above. Nevertheless the pebbles are, on the whole, rather evenly distributed throughout the other materials, instead of being concentrated in definite belts and layers.

Topographic relations.—The high-level Jamesburg is known to reach an altitude of 214 feet, but it is not known that this is its maximum height. The low-level phase is sometimes not more than forty feet above the sea-level.

Occasionally the formation is disposed in the form of rude terraces. It is possible that such parts, as well as the covering of some of the broad flats along valleys, are of sub-aërial origin.

One of the most striking characteristics of the Jamesburg formation is its relation to the pre-Jamesburg topography. From the higher points within the area where the Jamesburg and Pensauken formations are distributed, frequent views can be had which show the existence of well-developed systems of valleys, which are altogether out of keeping with the existing streams in the matter of size. Some of them, indeed, are not occupied by streams at all. The main valleys of these systems are broad and shallow, and their tributaries have a similar character, indicating that the streams which made them

had a long history. The forms of the valleys show that the streams which cut them were not rapid streams, and that the surface of the land was not high during their excavation. Clear as it is that these systems of depressions are river valleys, examination of the details of their topography makes it clear that there are many minor features which are not the result of erosion. The slopes to these broad valleys are not always erosion slopes, so far as the details of their surfaces are concerned.

Topography of the formation.—The Jamesburg formation mantles the valleys and the low divides between them. It is superimposed upon an erosion topography, but disposed with sufficient irregularity to give rise to certain distinctly non-erosion features. Quite apart from its topographic distribution, then, the Jamesburg formation has a topography of its own, which is not its least significant feature. The topography of the formation, as distinct from its topographic relations, is the topography for which the disposition of its material is responsible, independent of its base.

There are two types of topographic features, due to the irregular disposition of the Jamesburg material. These are—1°, low curved ridges, and 2°, saucer-shaped depressions. The little ridges are three to ten feet in height, have a width of twenty to forty feet, and a length of forty rods or less. Cross-sections of them have been seen now and then, and they have a concentric structure, the center of which is not in the center of the ridge, but on its concave side. These ridges are by no means co-extensive with the formation, and are much more commonly developed along the pre-Jamesburg valleys and slopes than elsewhere.

The other topographic feature, the sinks, is much more widespread. They are often associated with the ridges, but occur at many points where the ridges do not. Indeed, they are essentially co-extensive with the formation itself. Certain points in their distribution will be noted farther on.

The little ridges often run out from slopes into the valleys, or on to the lower land adjacent. Several of them are sometimes associated, forming tangles of ridges, which then inclose shallow, undrained depressions. Where the ridges and intervening depressions are abundantly developed, the topography sometimes takes on an aspect which suggests the topography of weakly-developed moraines. Analysis of the topography shows that it really differs from that of a moraine,

chiefly in that there is a certain system in the arrangement of the depressions. They also appear to be somewhat definitely related to each other in the matter of size. This arrangement often stands in a definite relation to the arrangement of the valleys, and to the erosion topography beneath the Jamesburg.

The following features and relations occur with sufficient frequency to be designated as general characteristics, though they are not to be seen everywhere: 1°. In any restricted area where the depressions are abundantly developed, they have an approximately constant depth. Thus, in any region where a depression is three feet deep, the adjoining depressions will be found to depart but little from this depth. 2°. There is a general relationship between the depth of a depression and its diameter. A depression three feet deep is usually three or four rods wide, while one ten feet deep is fifteen to twenty rods wide. 3°. A line may be drawn connecting any two of these basins without possessing significance; but if three basins be found to be lineally arranged, other basins are likely to be found in the same line. In such a linear series the individual depressions are likely to grow progressively larger from one end to the other (a partial exception to 1° above). In the direction in which the depressions increase in size, the series is likely to connect finally with some gully or small valley. In regions where the depressions are few and single, nearly all of them are found at the heads of small valleys. 4°. Where the ridges are numerous and have various courses, undrained depressions are necessarily formed by their intersections. Many depressions, however, have no relation to the little ridges. They frequently occur on plains and along valleys where the ridges are absent. The depressions are likely to be found in cols across divides which separate considerable drainage systems. 5°. The ridges are especially well developed along the line a little northwest of the center of the Bordentown-Raritan bay trough. This is the line where the Raritan clay occurs, and it is also the lowest line along the trough. The latter consideration is probably the one which has determined their presence. 6°. Within this area, the ridges are best developed along lines marking changes of the slope from a higher to a lower level, and especially on the slopes to broad valleys. They often run out into valleys, and sometimes entirely cross them, thus interfering with drainage and giving rise to marshes. 7°. In some instances there seems to be a relationship between the little ridges and the angle of the slope from

which they project. So far as such relation can be said to exist, the ridges seem to be longer on the gentler slopes, and shorter on the steeper ones. 8°. Where the small ridges are developed, they are usually even-crested, narrower and higher at one end, and lower and broader at the other. Besides being curved they are often hooked at the lower end. Branches are sometimes given off from their convex sides. The secondary ridges are never higher than the point at which they leave the main ridge. 9°. The material of the ridges generally resembles the material of the higher land from which they jut, more closely than the material of the formation immediately beneath them.

Thickness.—The thickness of the formation varies from nothing to thirty feet. Nowhere does it attain so great a thickness as that represented by the latter figure, except where pre-Jamesburg valleys have been filled with it. At the higher levels, its average thickness can hardly exceed five feet, and in many places it does not exceed three.

The origin of the formation.—Until the whole area of the formation has been studied with care, all conclusions concerning its origin must be regarded as tentative. It seems certain, however, that the formation was produced during the submergence of the area which it covers. There seems to be no other explanation of the high-level portion of the formation possible, and submergence of the areas where the high-level portion of the formation is found must have involved, necessarily, the submergence of the areas where the low-level portion is found.

It will be recalled that the Jamesburg is locally a glauconitic loam, mingled with gravel, and that this phase of the formation is found at the highest levels where the formation is known. The association of gravel with the loam makes it certain that it is not an eolian deposit. The fact that the gravel contains, in some places, *water-worn bits of iron-stone, derived from the indurated parts of the underlying Pensauken*, shows that water was the agent concerned in its deposition. Locally the stratification of the deposits is clearly such as water alone could produce.

The little ridges which have been noted are confidently believed to represent the work of waves and shallow water currents. It is not easy to see how otherwise they could be built out across valleys, or how they could be built half way across them.

There is, furthermore, the singular phenomenon of well-developed systems of erosion valleys out of all keeping with the streams that occupy them, and in some cases without streams of any sort. These valleys were developed after the Pensauken deposition, as shown by their relation to that formation. These valleys, as well as the intervening divides, are mantled by the Jamesburg. The depressions and little ridges referred to often affect these valleys, some of which appear never to have possessed streams since the Jamesburg was deposited.

It would be possible to think of the shallow depressions as being due to the subjacent formations, *e. g.* to its unequal settling. In this connection it may be recalled that they are best developed over the Raritan clay and clay marl formations. But similar depressions do not affect the surface of these formations where the Jamesburg is absent, and similar depressions are present when the underlying formations are not Raritan clay or clay marl.

The ridges, on the other hand, do not appear to stand in any other than an accidental relationship to the underlying formations. In many cases the ridges are responsible for the sinks, as already noted, and the more rational conclusion seems to be that the two features have a common origin.

If the formation was produced by submergence of the area which it covers, there were two epochs, one during submergence and one during emergence, when each part of the surface was at sea-level. Effective wave action on the surface at any given level was limited to the time when the water was shallow. In the case of the broader shoals, the effect of the waves would be to develop them into flats, bearing the material cut off from these surfaces to the deeper water about them, thus enlarging by deposition the flat produced by planation. If some such action as this has taken place, the time involved being short, it would have left the surface very much as we find it. From the shoals, waves and currents would have built bars and spits here and there. These are believed to be represented by the ridges referred to in the foregoing pages, although their constitution does not always seem to necessitate this conclusion.

At certain stages of the submergence, and again at corresponding stages of emergence, the cols along the divides were converted into little straits connecting the larger bodies of water on either side. At these stages the higher hills and ridges were islands. Through these

little straits the tides and waves worked with more or less force, and might have given rise to the phenomena which are found in these positions.

Examination of the coast survey charts of various parts of the Atlantic coast shows the existence of topographic features which seem to be similar to those of the area under consideration, in the shallow water off shore. So far as can be made out from the data of these charts, there appear to be low, ridge-like swells, often curved in form, associated with, or sometimes even inclosing basin-like depressions, comparable in all respects to those which affect the surface of the land area.

As seen on the coast survey charts, these depressions are often eight to ten feet deep. They are especially well shown on chart 180, on the west side of the peninsula of Florida, but they may be seen in greater or less development on almost any of the charts from New York south, where there are small islands connected by shoals.

Topographic features of this sort affect the coastal plain area in various localities far south of New Jersey. The sinks, the ridges, and the undulating topography to which their association gives rise, are well seen in some parts of Delaware and Maryland, and perhaps still farther south.

A further reason for believing that the formation was laid down during submergence of the area it covers, is found in the presence of glaciated bowlders, in positions which glacier ice did not reach, and in positions to which streams could not have carried them. The only agent which seems competent to account for them is floating ice, and floating ice means submergence. The period of submergence must have been short, since the thickness of the formation is so slight.

While submergence would seem to account for the phenomena of the Jamesburg formation, there is a difficulty in accounting for the absence of certain phenomena which, under this hypothesis, it might be thought should be present. Here may be mentioned the fact that distinct shore lines for the Jamesburg sea are wanting, and the further fact that marine fossils have not been found in the formation. The absence of fossils from the high-level part of the formation at least, is not strange. The deposit is so thin that surface-weathering might easily have destroyed them. The absence of shore lines was long regarded as an almost fatal objection to the submergence theory; but the growing body of evidence has led to the conclusion, concerning

which no doubt is longer entertained, that this is the real explanation of the origin of the formation. It may be that the absence of distinct shore lines needs explanation, but this must be found in some other direction than by denying the submergence.

Where the pre-Jamesburg erosion had advanced so far as to develop broad low-level flats, Jamesburg material must have been deposited on them at the same time that the high-level Jamesburg was being deposited. During the emergence of the land which followed the deposition of the high-level Jamesburg, sedimentation must have been continued over the lower surfaces after it ceased on the higher. A part of the low-level Jamesburg is therefore quite certainly contemporaneous with the high-level part of the formation, while another part of it is younger. How much younger is not now known. Neither is it known whether all which is classed as low-level Jamesburg was really continuous in origin, following on from the date of the high-level portion of the formation. It is possible that the low-level Jamesburg of the valleys, especially that which is disposed in the form of terraces, was deposited by streams and not by the sea. It is very probable that definite subdivisions of this formation may yet be established.

Age of the Jamesburg.—The amount of erosion accomplished since the deposition of the Jamesburg is slight. This is shown not only by the various facts already mentioned respecting the undrained depressions along the axes of valleys, but also by the undissected flats of this material even where in close association with considerable streams. Perhaps the most notable of these is the uneroded surface northeast of New Brunswick, toward Bonhamtown. Either the formation is very recent, or conditions since its development have been most unfavorable for erosion. In many places the constitution of the formation is such as not to facilitate erosion, since it is so porous as to allow precipitation to sink beneath the surface rather than to force it to flow off over it.

The presence of glaciated bowlders in the Jamesburg formation seems to connect it with some stage of the glacial period. The bowlders are of the type which belong to the extra-morainic, and not to the morainic drift. This would seem to place it before the last glacial epoch. Its relation to the Trenton gravels points in the same direction. Yet the small amount of erosion which it has suffered seems hardly consistent with its correlation with the earliest glacial

epoch. The presence of the "old" drift type of bowlders might be accounted for, if it be supposed that the old drift was already in existence when the Jamesburg was developed. The exact age of the Jamesburg, in terms of the glacial period, is one of the questions which awaits solution, so far as New Jersey is concerned, though it is not believed to be insoluble.

The time relations of the low-level Jamesburg are even more uncertain. It seems certain that this portion of the formation is in part younger than the other, and some of it may be much younger.

SECTION VIII.

POST-JAMESBURG FORMATIONS.

Along the valley of the Delaware, reaching up to elevations of about sixty feet in the vicinity of Bordentown, but declining gradually to the southward, there is more or less sand, gravel and loam, which is later in origin than the Jamesburg formation. The following section at Edgewater Park, at an elevation of forty feet, indicates the character of the later formations as seen at various points:

4. Two to five feet of yellow sand—probably eolian.

3. Five feet of dark-colored clay, somewhat resembling certain subdivisions of the Clay Marl series, but unlike the clay marl in that it does not carry iron pyrites or glauconite. It is greasy to the touch in some places, and gritty in others. It is horizontally bedded, and in places laminated, the laminæ being somewhat irregular.

2. Ten feet of sand, the upper half quite like that at the surface. The lower half contains many bits and grains of shale and greywacke, which strongly suggest its correlation with the glacial gravels and sand of Trenton.

1. Two feet of gravel, in which quartz greatly predominates. The other materials are not such as to be altogether unequivocal, but they strongly suggest the correlation suggested by the sand.

The type of gravel found at Edgewater Park is seen at other points along the Delaware river, from Edgewater Park to Florence, on the north, and to Philadelphia, on the south. The gravel sometimes appears in the form of little knolls without covering of other material. More commonly it is overspread by sand containing the greyish materials noted above. Much of this sand may perhaps be of eolian origin, but it appears to have been derived from the Trenton gravel material.

At several points along the Delaware, clay loam is found having a chocolate-brown color. This may be seen a mile and a half southwest of Kinkora, where it is used for brick; at Kinkora, where it is stripped off from the surface of the main clay pit; a mile southwest of Fieldsboro, at Graham company's clay pit; and a mile and a half northeast of Bordentown. At this point, the section is as follows:

3. Five feet of dark-colored clay loam, more or less mottled with yellow.

2. Two feet of sand and gravel.

1. Cretaceous clay, Clay Marl series.

This surface loam and clay loam along the Delaware seems to be disposed on a plain which gradually rises from about thirty feet at Edgewater Park, to about sixty feet at Bordentown. South of Florence, this clay loam overlies sand, the constitution of which indicates that it is to be correlated with the glacial gravels of Trenton. Northeast of Florence the clay loam is more commonly underlain by gravel. At Holmesburg Junction, Penna., six to ten feet of stratified sandy loam overlie sand and gravel of the Trenton gravel series.

There is some indication that the valleys of the streams tributary to the Delaware river from Crosswicks creek, south to Rancocas creek were filled up to about the level to which this clay loam rises, at the time it was deposited. The effect of this filling can be traced up these tributaries for distances varying from three to six miles. The evidence seems to point to the correlation of this loam with the last stage of the deposition, of which the Trenton gravels are the first. The correlation of these young formations bordering the lower course of the Delaware river and Delaware bay, can only be finally made by carrying the study farther south, and determining its connections in that direction. It is well-nigh certain, however, that it will be found to connect with what was described as the fourth phase of the "yellow gravel" formation in the Annual Report for 1893. This covers the surface of the eastern and southern portions of the State up to an altitude of forty to fifty feet. It is possible that a part of the low-level Jamesburg of the valleys of South Jersey is to be correlated with this formation, occupying the lowlands about the coast. In that event it is clear that the Jamesburg must be subdivided.

SECTION IX.

ROAD MATERIAL.

From the standpoint of road construction, the State may be divided into five unequal areas. These are—1°, the area east of the highlands and north of the moraine; 2°, the highland area; 3°, the area west of the highlands as far south as the border of the Triassic area; 4°, the Triassic area outside the moraine; 5°, the area south of the Trias. While the regions thus defined are not always very distinct, still the problems and the difficulties presented are somewhat different in these several tracts, and somewhat similar within the limits of each.

1. In the northeastern part of the State the surface material is not well adapted for roadbeds. This is the region where stratified drift is most abundant, and the stratified drift is usually too sandy to make good roads. Where the drift is of the other type (till), it is often too clayey for road purposes, so that good highways can be secured only by the use of some material which shall be free from the disadvantages both of clay and of sand.

Much attention has already been given to the construction of roads in this part of the State. The inexhaustible supply of trap rock, which furnishes material admirably adapted for roadbeds, has already been drawn upon to a large extent. The results speak for themselves. Where this material is available, nothing else is likely to be extensively used.

2. The highland area (crystalline schist) of the State is much less densely populated than the preceding, and, in consequence, less attention has been given to the construction of roads. In many parts of this region, the nature of the soil and surface material are such that fairly good roads have been secured without the expenditure of great labor. There is an abundance of gravel, though it is less well distributed than could be desired. On the whole, it is too loose, too free from binding material, to give the best results. A slight admixture of some substance which would help it to pack, such as clay, loam, shale or trap, would add greatly to its value. It is probable that a judicious use of the materials at hand would obviate the necessity of importing crushed rock or anything else.

3. In the Kittatinny valley the drift is composed largely of shale and slate, and is, in consequence, of such composition as to make road construction an easy matter. Even where the drift is thin, or essentially absent, the problem is not more difficult, since the slate itself gives a roadbed which leaves little to be desired. Where the drift does not give a good roadbed directly, and it is sometimes too sandy, shale or slate gravel is usually within easy reach. The problem of good roads in the northwestern part of the State presents no serious difficulties, so far as proper material for roadbeds is concerned.

4. Throughout most of the Triassic area south of the glacial drift, the shale and the products of its decay affords roadbeds which are fairly good most of the year. In many parts of the tract, trap is accessible if anything needs to be added, and in a few places there is gravel of excellent quality. It is only where the surface is too flat for good drainage, that the construction of fairly good roads is likely to be difficult or expensive. Throughout much of the area it is true that the addition of trap to the roadbed would be an improvement, and an improvement which would be notable especially during times of excessive moisture or drought.

5. South of the red shale area, the road problem is a much more serious one. In this, the larger part of the State, the surface materials are of such a character that they do not usually give good roadbeds directly. Much of the surface is so sandy that even passably good roads can be had only by the addition of foreign material. Where the surface is gravelly, the gravel is often so free from binding material that it will not pack. Throughout most of this area, road beds must be made, if roads are to be in good condition at all seasons of the year, and in all conditions of moisture and drought.

There is no local source of trap in this part of the State. Neither is it so connected by railways or canals with the region where trap occurs, as to render the importation of this material inexpensive. It follows that any local supply of good material for the construction of roadbeds is of especial importance. Fortunately, there is an abundance of gravel, some of which is of such a character as to be admirably adapted for immediate application to the roads. To be adapted for immediate application, gravel must have the proper degree of coarseness, and must have either 1°, a matrix which will cause it to pack or "bind" in the roadbed; or 2°, it must contain some

physical element which will crush under traffic, thus furnishing the material which will act as a matrix. Gravel of both these types is found in abundance in many localities, but it is by no means distributed over the total area under consideration.

Gravel of the first type is found in many places where the Pensauken is well developed. In a few places gravel is found with so much iron oxide coating its pebbles, that this takes the place of a matrix. This sort of gravel occurs at Shark River.

So far as concerns gravel of the second type, viz., that which contains physical elements which will crush under traffic, attention may be called to two constituents which are often present. These are—1°, bits of ironstone, which are sometimes very abundant in the Pensauken and later formations, and 2°, bits of decomposed chert, which are found especially in the Beacon Hill and Pensauken formations. As constituents of the Pensauken and later formations, the bits of ironstone are derived chiefly from the indurated layers or laminæ of the Cretaceous and Beacon Hill strata. As constituents of the Jamesburg, they are derived from the same formations, and from the Pensauken besides. In the Jamesburg formation, gravel of this sort is often found in valleys which have their sources in Cretaceous hills, which are capped with remnants of Beacon Hill material. The streams have carried down the iron crusts from both formations, along with quartz pebbles from the upper one, and have deposited the two together.

The gravel, of which the ironstone is a constituent, is by no means confined to valleys. While it is widespread, it is found abundantly only in those regions where there were hills and ridges composed of the Cretaceous strata at the time the Pensauken formation was deposited. This general principle defines the area where the ironstone-bearing gravel is plentiful. It is found especially along a belt southeast of the trough referred to in the preceding pages—that is, along a belt extending from the Navesink Highlands, on the northeast, through the Mount Pleasant hills and the Clarksburg hills, to Arney's Mount, on the southwest. Within this area, gravel which is composed largely of ironstone, is of frequent occurrence, and gravel which has enough ironstone to allow it to pack, is still more widely distributed. Nevertheless, the supply is limited, since it often occurs in small beds only. The ironstone is mainly in the form of flat chips, a fraction of an inch thick, but always water-worn. These chips

break and crush easily under the wheels, so that their presence in proper quantity constitutes the gravel containing them an excellent road material.

There are several other classes of material which are, or may be, used directly with more or less success for the construction of roadbeds. There is 1°, a variety of coarse, more or less arkose sand, such as often forms the matrix of gravel in the Pensauken formation. It is found in the Pensauken formation, at many points, constituting, indeed, its sandy or loamy member. 2°. Gritty marl. This is referable to one of the formations later than the Beacon Hill, mainly Jamesburg. It consists of Cretaceous marl, worked over and mixed with more or less coarse sand. This type of material may be seen a short distance northwest of New Egypt. 3°. Bog iron ore, which crushes readily and gives a hard roadbed, occurs in considerable quantity in various marshes. One locality, where it is abundant, is a mile or so northwest of Perrineville. It will probably be found to exist in many marshes where it has not yet attracted attention. 4°. There is, in many places, an abundance of gravel which has too little matrix, or too sandy a matrix, to give roads of the highest excellence, but which is still much better than nothing, for use upon the highways.

While all the materials mentioned in the preceding paragraph have been used to greater or less extent, their possibilities have by no means been exhausted. While each of these materials, taken by itself, will serve to improve bad roads, it is probable that the greatest value of each will be found to be in combination. The gritty marl, the bog ore, and the arkose or mealy sand, will each be better in combination with gravel than alone; and since gravel is so much more abundant than the others, economy of material would urge their combination. This can be effected easily where the various sorts of material occur in closely associated localities. This is sometimes, though unfortunately not usually, the case. Where the gritty marl, the bog ore, and the arkose sand are wanting, there is frequently clay-loam which might be combined with the gravel advantageously. It is well-nigh certain that intelligent experimentation in the way of combining accessible materials would abundantly repay the cost involved.

In the more enterprising communities many excellent roads have been constructed of the local material derived from the Pensauken

formation, roads which are second only to the trap roads of the north-eastern part of the State. Many of the roads about Vineland, Bridgeton, Millville, Woodstown, as well as many country roads in the belt of rich agricultural land a few miles back from the Delaware, in the southern part of the State, are sufficient testimony to the excellence of the material. In judging of the qualities of this sand and gravel, for road purposes, from the roads where it has been used, account should always be taken—1°, of the care with which the foundation was prepared for its reception; 2°, of the amount of material used in the first place; 3°, of the care which the road has received since the material was first applied; and 4°, of the length of time during which the road has been in use. Where the material to be used on a road is cheap, there is always a tendency to make poor preparation for it—and to take little care of it after it is once applied.

Brief reference is here made to some of the localities where road material is found available either in its present condition or in combination. The references are by no means exhaustive, as much of the southern part of the State has not been studied in detail. Fuller data are at hand concerning the southern part of Mercer and Middlesex counties, and the western parts of Monmouth and Burlington, than for other regions.

Southern Middlesex county.—The available road material of southern Middlesex county consists of gravel, with a loamy or arkose matrix, and a small amount of bog iron ore. In many places, the gravel has a matrix such that it packs well in the roadbed, as taken from the pits. In other cases, the matrix is of such a character or quantity, that combinations of material might be made advantageously. Some of the more important localities where available road material occurs are as follows: In the vicinity of South Amboy, much that is good for immediate application, and much arkose sand that would be improved by the addition of gravel; in the vicinity of Old Bridge, especially to the northwest; at several points northeast of Milltown, within a mile or two of the village; one and one-half miles northwest of Spotswood; in the southwest portion of South Brunswick township, as, for instance, a mile southeast of Fresh Ponds; a mile and a half southeast of Dayton, and northwest of the same place; at Kingston; north of Red Tavern (Monroe township); south and west of Old Church, especially on the hill-tops; about Half Acre, and thence southeast to Gravel Hill; south and southwest of Jamesburg;

at various points on the highlands between the State Reform School and Englishtown; on some of the high inter-stream areas of Cranbury township; and along some of the stream-flats, as a half a mile below Cranbury mill. Most of the gravel here referred to belongs to the Pensauken formation, though that along the stream-flats is younger.

Southern Mercer county.—At various places in the part of Mercer county under consideration, the character of the surface material is such as to afford moderately good roadbeds without the addition of any sort of material. There are relatively few areas where the supply of good road gravel is abundant, though there are many local beds of gravel, which are sufficient for local needs. Mention may be made of the arkose sand at Hightstown, which would bear admixture with gravel, and of gravel at various points in Hamilton township, in the vicinity of Hamilton Square, Mercerville (Sandtown), Dogtown, White Horse and Lawrence station. The road material of these localities belongs to the Pensauken formation. Much of it contains constituents which crush readily, and so supply the material for rendering the roadbed compact.

The northwestern part of Burlington county.—That part of Burlington county which has been studied in detail, has an abundant supply of road material. While much of it is of such a character that it can be applied to the roads directly, more of it could be mixed advantageously with material which would help it to pack more readily under traffic. Even this latter class of material must be regarded as available for the construction of roads. The road material of this county may be grouped as follows:

1°. *Gravelly loam.*—In this class of material it frequently happens that loam and gravel are associated in about the right proportions to make good roadbeds. It is also common to find the gravel without sufficient loam, or with none at all. In such cases a slight admixture of clay or marl will supply the deficiency. The matrix of the gravel is sometimes sharp sand, associated with some white, kaolin-like substance, which helps the whole to pack under the wheel. When the same sort of sand occurs alone, as is sometimes the case, it often packs well in the roadbed, but does not appear to be very durable under heavy traffic. The materials classed under this general heading sometimes vary too far in the direction of coarseness, containing considerable quantities of cobbles, which need to be removed before application to the roadbed.

Areas where gravelly loam occur are mostly near the Delaware, especially on the higher lands between the tributaries to this stream. Tracts of greater or less extent within which this type of material is abundant, occur east of Bordentown, and between that city and Crosswicks; a mile southeast of Crosswicks; northwest of Mansfield Square; between that place and Fieldsborough; a mile or less east of Kinkora; about Bustleton; a few rods northeast of Deacon's station; half way between Deacon's station and Burlington, on the south side of the railway; in the vicinity of Rancocas; and two miles south of Burlington.

All of these areas of gravelly loam are remnants of the Pensauken formation which have escaped destruction by erosion. They are all at elevations ranging from 70 to 100 feet, the lesser figure belonging to the areas farthest to the southwest. The total area of these several patches amounts to something like sixteen square miles, and the average depth of material is probably about ten feet. It is not to be inferred, however, that all the gravelly material to a depth of ten feet within the tracts noted is good for road purposes. Rather should it be understood that in these various areas there are considerable beds of loamy or sandy gravel capable of furnishing materials which, either in themselves or in combination, are valuable for the construction of roadbeds. Gravel pits have already been opened in all the places mentioned, and in many cases experience has shown that the material, as taken from the pits, is of excellent quality.

Ironstone gravel.—Another type of gravel which is available for the construction of highways occurs in limited patches over a belt of territory somewhat farther east, lying between Ellisdale and Walnford on the northeast, and Jobstown on the southwest. This second type of gravel consists of bits of ironstone, together with small pebbles of quartz. The gravel frequently has a matrix of marly clay and sand. The especial excellence of this type of material inheres in the abundant pieces of ironstone, which crush readily under the wheel and afford an excellent matrix for the other constituents of the gravel. Unlike the preceding type, this gravel rarely contains stones which are so large as to be objectionable, and a much larger percentage of it is in such a condition as to make it available without the admixture of foreign ingredients.

A number of points are known where this sort of material occurs, but unfortunately beds of it are often extremely local. It is probable

that it exists at many points where not exposed, but its distribution is so fortuitous as to make its discovery difficult without actual excavation. It is known at the following places: Three-quarters of a mile south of Walnford, three-quarters of a mile west of Arneytown; at several points just east of Chesterfield within the distance of a mile; at several points between Chesterfield and Georgetown, a mile northwest of the latter place, and on several summits south and southwest of it, within the distance of a mile or two; at Mansfield, at a point a mile and a half west of south of Jobstown, and a mile east of north of Juliustown. Like the preceding type, this gravel occurs mainly on summits and divides, and at similar elevations. Like the other also, it belongs to the Pensauken formation. The ironstone gravel is much less extensively developed than that of the preceding type, but most of it is immediately available.

Quartz gravel.—The third type of gravel consists principally of small quartz pebbles. In itself it does not always pack well, but with a slight admixture of the proper sort of binding material, much of it would make excellent roadbeds. Some sort of marly loam would supply its inherent deficiency. This type of material is found at intervals from Arney's Mount to Arneytown. It occurs in Arney's Mount, in the ridge south of Juliustown, on the summits north and south of Fountain Green, between Wrightstown and Springfield; short distances southeast and also west of Sykesville, and on several of the summits within a mile to the northeast, north and northwest of that place. It appears again just north of Jacobstown, and between Jacobstown and Arneytown, as well as a half mile east of that place. This class of material belongs largely to the Beacon Hill (Miocene), though some of it is to be referred to the Pensauken.

Gritty marl.—A short distance northwest of New Egypt there is an area where marly clay exists, containing a very considerable amount of sharp, coarse sand. It has not been sufficiently used to establish its merits as road material, but temporary results from its use seem to be good. Similar gritty clay is found at various points from Juliustown to Springfield Church, and thence to Georgetown, but it has not been brought into general use. Northeast of New Egypt this type of material is common along the border of the pines, and in that region it is often the only available road material. Geologically, this material belongs to the Jamesburg formation.

MONMOUTH COUNTY.

Western Monmouth county.—In the western part of Monmouth county (that part which appears on sheets 8 and 12), there is an abundance of road material of variable quality, but it is not altogether well distributed. In some considerable tracts there is no gravel, while in others it is abundant, but unfortunately not associated with loam or anything else which gives it the packing quality.

Millstone township is much better supplied with material which can be used for roadbeds than any other portion of western Monmouth county. Within this township lie the Perrineville-Clarksburg hills, in which there is an abundant supply of gravel, though much of it has too little matrix to make it immediately serviceable. There is here a considerable amount of gravel, however, which has the proper sort of matrix in proper quantity. One of the best exposures of gravel of this sort occurs in the hill-top a mile east of Perrineville, and about eighty rods north of the road, while another pit of excellent material is situated a mile northeast of Clarksburg.

Nearly all the hills from Pine hill southwest to Clarksburg are capped with gravel (Beacon Hill) to a greater or less extent. On the slopes of these hills also, and on the benches against their slopes, there is frequently a sufficient accumulation of gravelly material to be workable. The gravel on the slopes (Pensauken) does not generally pack so well as that upon the hill-tops, chiefly because it is essentially wanting in the decayed and easily-crushed chert, which is a constituent of the high-level gravels. In some localities, on the other hand, the low-level gravels contain a considerable quantity of ironstone in small pieces, and this serves the same purpose as the chert.

A mile northwest of Perrineville there are a number of marshy areas where bog iron ore occurs in considerable quantity. This ore is likely to prove one of the most important local sources of road material. Its most economical use will probably be found to be in association with gravel, for it will supply the proper binding material for a large body of gravel which otherwise would be of little value. Aside from the bog ore just referred to, there are a number of swamps and marshes in this township where considerable quantities of similar material are known.

The hilly eastern portion of Upper Freehold township has road material comparable to that of Millstone township in kind, quantity

and distribution. Here, as there, gravel is found upon the hill-tops, as well as on their slopes. The latter is often better than the former, because of its abundant content of ironstone chips. Outside the hilly part of the township, gravel of good quality is found in many places, but beds of it are not extensive, and considerable tracts have none.

Other areas.—There are many localities outside the area which has been studied in detail where road material of good quality is known to occur. The following list of localities where pits for road material have been opened, while not exhaustive, may serve to show how widespread available material is. In many localities the gravel is of high grade and ready for application to the roadbed, as taken from the pit. *Ocean county,* 1°, two miles south of Lakewood; 2°, east and northeast of Toms River, where indifferent material has been used so as to make fairly good roads; 3°, near Staffordville. In *Burlington county,* in addition to localities heretofore specified, 1°, at Woodmansie. In *Camden county,* 1°, two miles southwest of Marlton; 2°, at various points two and three miles northwest of Berlin. In *Gloucester county,* 1°, near Pitman Grove; 2°, at Jeffersonville, a mile or more northeast of Mullica Hill. In *Salem county,* 1°, at Woodstown; 2°, a mile northeast of Woodstown, at Point Airy; 3°, near Daretown; 4°, at points near Richmanville; 5°, two miles south-southwest of Alloway, near the triangulation station, Burton; 6°, at Cohansey. In *Cumberland county,* 1°, at several points west of Bridgeton; 2°, one and one-half miles northeast of Bridgeton; 3°, a mile northeast of Millville depot; 4°, west of the river at Millville; 5°, several points near Vineland.

At most of the places here mentioned, the material is from the Pensauken formation. It is safe to say, that wherever this formation is present, there are good possibilities in the way of road material. Hundreds of places could be located, on the basis of present geological knowledge, where good road gravel may be found and easily obtained. There are many large areas where good roads are almost unknown, where excellent material is close at hand, and could be had for little more than the cost of the labor involved.

SECTION X.

EXPLANATION OF THE GEOLOGICAL MAP OF THE SURFACE FORMATIONS OF THE VALLEY OF THE PASSAIC AND SURROUNDINGS—SHEET 6.

The geological map accompanying this report, and covering the area of sheet 6 of the topographic atlas, is a preliminary map of the surface geology of a considerable section of northeastern New Jersey. The surface formations are those which lie at the surface, without regard to their age. They do not belong wholly to any one period of geological history. Some of those represented on the map belong to an early stage of that history, and they appear on the map because they are not overlain and concealed by other formations of later age.

Complex as the map may seem at the first glance, a few general statements will suffice to make its leading features clear.

In the eastern and northeastern portions of the map the dominant color is green. This color represents the area where the surface formation is unstratified drift till* deposited by glacier ice during the last glacial epoch. The ice advanced from the north-northeast, and the southwestern limit of the green color (dots and circles) represents the limit of its movement. A general map of the State, accompanying the Annual Report of 1893, shows the total area of the State covered by ice during the glacial period, and reference to it will make clear the relations of the glaciated area of sheet 6, to the glaciated areas farther east and west. While all the green of the map (except the yellow-green lines in the southeastern corner) represents glacial drift of the last ice epoch, it is to be noted that a belt of green, darker than that of most of the map (dots instead of circles), extends from Perth Amboy on the southeast to Rockaway on the northwest. This darker green represents a belt of thick drift, marking the position where the edge of the ice stood for a considerable period of time. This belt of thick drift is the terminal moraine† of the last ice epoch.

*See Annual Reports of the State Geologist for 1891, pages 66–71, and 1892, page 28.

†See Annual Reports of the State Geologist for 1891, pages 81–6; 1892, pages 39, and 73–8; and 1893, pages 124–151.

It does not represent the outermost limit which the ice ever reached, but it marks the position where the terminus of the ice lay for a period sufficiently long to accumulate a very considerable thickness of drift. Outside the terminal moraine, that is, to the west of it, there are a few small areas of glacial drift, also represented by green, which are believed to have been deposited by the ice of the last glacial epoch, which, at some stage in its history, advanced a little beyond the position of the moraine.

A special phase of the till is differentiated from the main body, and designated drumlins.* Drumlins are not numerous. Such as exist within the area covered by this map are to be found north and northeast of Newark. The legend indicates the manner in which they are represented.

Associated with the green color on the map, there are many areas of yellow. These lie partly on one side of the moraine and partly on the other. They represent the stratified drift deposits made by the waters resulting from the melting of the ice. When the edge of the glacier occupied the position of the moraine, the waters produced by its melting, and flowing from it, carried sand and gravel far beyond. This is especially notable in the area extending from Plainfield to Bound Brook and beyond, and in the area south of Morristown, where Lake Passaic lay when the ice edge stood at the moraine.

As the ice melted back to the northeast, the waters arising from its wastage deposited more or less sand and gravel along the lines of drainage, thus giving rise to stratified drift northeast of the moraine, and represented on the map by the yellow-colored areas in that position.

The stratified drift assumed different forms in different positions. Outside the moraine it was sometimes deposited in the form of plains (overwash plains),† as from Plainfield to Metuchen, and sometimes in the form of narrow belts along valleys (valley trains).‡ Within the area covered by the ice, it sometimes assumed the form of hillocks (kames),§ especially where the water issued from beneath the ice.

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* See Annual Report of the State Geologist for 1891, pages 71-5.

† See Annual Reports of the State Geologist for 1891, pages 95-9; and 1892, pages 40-1 and 96-102.

‡ See Annual Reports of the State Geologist for 1891, pages 96-8; and 1892, pages 40-1 and 102-4.

§ See Annual Reports of the State Geologist for 1891, pages 92-5; and 1892, pages 42, 84, *et seq.*

The kames are represented on the map as distinct from other phases of stratified drift, as shown in the legend, but it is sufficient here to emphasize the fact that all the areas colored yellow are covered by stratified drift deposited during the last glacial epoch. Within the moraine the stratified drift deposited by glacial waters often overlies and conceals the drift which was deposited by the ice itself, at a slightly earlier time.

To the stratified drift of the last ice epoch belong also the few eskers* represented by the narrow belts of red dots, such as that running from Afton to Hanover. The eskers are in all cases narrow ridges. Their origin has been elsewhere discussed.

The special significance of the terms used to designate the several phases of drift may be ascertained by referring to the recent annual reports. The volumes and pages where the terms are defined are given in the accompanying foot-notes.

It is to be remembered, then, that the green dots and circles represent the deposits made by the glacier ice of the last ice epoch, and that the yellow dots and circles, and the small red dots arranged in narrow belts (eskers), represent the deposits made by glacial drainage during the same epoch. With this in mind, it is to be noted that in the southwestern portion of the area covered by the map, the colors are such as to throw this part into sharp contrast with the area covered by the glacial drift. Barring the yellow, which has already been explained as belonging to the drift, there are three principal formations represented in the southwestern part of the map, marked by the brown dashes, the blue lines and the red checks respectively. There are also two subordinate devices, viz., the orange dots, especially in the western and southwestern portions of the map, and the red circles in the southern and southeastern part. All areas marked by these devices were beyond the reach of the ice of the last glacial epoch.

The brown dashes, covering the area west of Morristown, represent the schist and gneiss formation of the crystalline highlands, where the same is not concealed by later formations. The schist and gneiss underlie some of the glacial drift in the northern part of the area covered by the map. Within the area marked by the brown dashes, the surface soil and subsoil were produced chiefly by the decomposition of the underlying rock. While the schist and gneiss

*See Annual Reports of the State Geologist for 1891, pages 89-92; and 1892, pages 41-2 and 79-83.

are very old, the soil and subsoil which covers them, and which was produced by their decay, may be relatively young, so far as its present condition is concerned.

The red checks represent the trap ridges known as First, Second and Third mountains, or collectively as the Watchung mountains, together with some minor areas of the same sort of rock. It is to be noted, however, that the red-checked areas represent only the southwestern ends of the mountains named. The northeasterly continuations of the same ridges were covered by the ice of the last glacial epoch, and the trap rock is there generally concealed by the deposits which the ice made. Nevertheless, the body of drift on the northeastern portions of these mountains is not great, and in many places the trap rock is but thinly covered. Locally, indeed, it is nearly bare. The attempt has been made to represent the fact that the covering of drift is often very thin, by letting the red checks, representing the trap, and the green circles, representing the till, appear together. This is shown at Livingston, at various points near Little Falls and Paterson, and in the vicinity of Whitehall. Where glacial drift completely conceals the trap rock, it is largely made of material derived from the ridges themselves.

The areas marked by blue lines represent the shale and sandstone of Triassic age—the Newark formation—where the same is not covered by any younger deposit. Like the schist and the trap, this formation underlies much of the drift. A map showing the surface geology, however, represents it only where it lies at the surface, unconcealed. Where the Triassic shale and sandstone formation is covered by glacial drift, the latter is composed very largely of material derived from the former.

The orange dots, such as appear south of Rockaway, about Mendham, and at various points between Bernardsville and Somerville, represent glacial drift which is believed to be much older than that of the areas colored green. This is the drift which has been referred to in preceding reports as extra-morainic.* Its occurrence in patches only, is believed to be due to the fact that much which was originally deposited has been removed by erosion. The scattering dots of this color on the crystalline schist area represent scattering bowlders of drift.

The red circles in the southern and southeastern portion of the

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* See Annual Reports of the State Geologist for 1891, pages 102-8; 1892, pages 60-72; and 1893, pages 73-123.

map represent areas where some phase of the "yellow gravel" series* is found. All formations of this series, from the Pensauken on, are represented. Where the circles are scattered over the area of Triassic shale, they represent a thin covering of the gravel, too thin to conceal the shale beneath. The yellow gravels were deposited during submergence of the areas where they occur. The isolated remnants near Hillsborough, Clyde, etc., show that much erosion has taken place since the deposition of the Pensauken. The Pensauken formation is shown at the pit at Bonhamtown. It is the oldest of the yellow gravel formations of the area covered by the map, and is usually covered by a thin layer of the Jamesburg, the next succeeding formation. The red dots covering the low lands about Raritan bay are of relatively recent origin, and correspond with the fourth stage of the yellow gravels, as set forth in the Annual Report for 1893 (p. 68).

The yellow-green lines which appear at a few points in the southeastern corner of the map, represent areas where the Cretaceous formation is not covered, or where it is but ill-concealed. Many of these areas are large clay pits, where the Cretaceous has been artificially exposed.

Wherever two or more colors or devices occur together on the same area, their association means that the two formations represented by the devices separately, occur together, so far as the surface is concerned. Thus in the southwestern part of the map, at the bases of the trap ridges, there is a commingling of the red checks, representing trap, and the blue lines, representing shale. This means that trap talus has descended the slopes of the ridges, and is mixed with the residual material arising from the decay of the shale or sandstone.

The alluvial plains along the streams are designated by a separate color, as shown in the legend, as also are swamps and marshes, and areas covered by wind-blown sand. When the latter is thin, as in the vicinity of Millstone, the dots representing the eolian sand are associated with the devices representing the next underlying formation, which, in this case, is red shale.

The heavy brown lines in the central part of the map represent the outlines of Lake Passaic.† Within that part of the basin which lies

*See Annual Report of the State Geologist for 1893, pages 53–72; also the sections of this report on the Pensauken, the Jamesburg and the post-Jamesburg formations.

†A map of Lake Passaic accompanies the Annual Report for 1893. For discussion of the lake, see Annual Reports for 1892, pages 126-144; and 1893 pages 225-328.

outside (west of) the moraine, there are occasionial small green circles, which represent bowlders, or small patches of drift, which are believed to have been carried to their present position by icebergs which floated out on the lake during the last glacial epoch.

It should be noted that the base on which the geology is represented is a topographic map. The contour lines are somewhat obscured by the colors, but in most areas they can be made out with little difficulty. Attentive study will bring out many interesting relations between the topography and the geology of the region.

EXPLANATION OF PLATES.

Plate 1.

Figure 1.—Profile of the gravel deposits and of the stream in the Flat brook valley. Line *a b c d* represents the aggradation level of the kame terraces to the recessional moraine (*d*) above Layton. The line *e f* represents the aggradation level from the Layton moraine to the moraine (*f*) near Montague. The line *g h* represents the aggradation level above the latter moraine. The gravel does not at all points reach the lines which here represent the aggradation levels, as the kame terraces are not continuous. The line *h i* shows the present slope of the Flat brook.

Figure 2.—Profile of the gravel deposits and streams in the sub-valley extending from Columbia to Deckertown (Paulins kill). The line *a b–h* shows the aggradation level of the terraces, kame terraces, and kames from Columbia to the recessional moraine near Balesville. The terraces do not at all points reach this height. They are at lower levels or wanting in many localities. The more notable interruptions are indicated between *b* and *c*, between *d* and *e*, and between *f* and *g*. At *i* the Balesville moraine crosses the valley. Line *k l* shows the slope of the low gravel terrace along the Paulins kill and its tributary from near the moraine to Branchville. The line *k m* shows the rise of this terrace in the main valley to the moraine northeast of Augusta. The line *k n* represents the gravel terrace along the Paulins kill as far as Lafayette. The line *o p* shows the aggradation level in the valley northeast of Frankford Plains; *q r* shows the aggradation level of kames in the Papakating valley northeast of Roy's Station. The broken line *p r* is the extension of the aggradation level *o p* to the high terraces at the mouth of the Little Papakating; *s t* shows the gradient of the Paulins kill from the Delaware to Lafayette. The line just below and parallel to *k l* shows the gradient of the Branchville tributary to the Paulins kill. The line *v w* shows the gradient of the Papakating creek from the divide northeast of Augusta to near Deckertown.

Figure 3.—Profiles of gravel deposits and present streams along the sub-valley from the moraine at Danville (Pequest), through Germany Flats to Van Sickles, northeast of Deckertown. Line *a b c d* shows the aggradation level of the stratified deposits from the moraine to a point above Huntsville. The line *e f* shows the aggradation level from Brighton to the moraine (*f*) north of Germany Flats. The dotted line *n o* shows the poorly-defined aggradation level of the Hamburg-Decker-

town kame-belt, the short lines below showing the heights of the principal kames. The dotted line *p q* shows the aggradation level of the kame-belt northeast of the Deckertown delta plain, the full line just below it showing the surface of the kames. *g h* shows the gradient of the Pequest river from the moraine to Huntsville; *h i* the gradient of the tributary along which this profile is taken. The lines *j k* show the gradient of the small streams draining part of Germany Flats, and the line *l m* the gradient of the present drainage through White lake and the Wallkill, as far as Franklin Furnace.

Figure 4.—Represents in profile the relation of the stratified drift along the valley of the Ramapo. *a b* represents the gravel aggradation level from Pompton to Oakland. Between these point deposition seems to have been continuous and uninterrupted. From *b* to *c* stagnant ice forms are developed with a nearly constant upper level. *e f* represents a delta-like body of drift. *g h* represents a stretch of gravel deposited while the ice edge stood at *h i*. *i j* represents another section of valley-filling, the deposits being made when the edge of the ice stood at some undetermined point north of the State line.

It is not to be understood that the gravel reaches the level indicated by these profiles at every point. The profiles are intended to express general relations only.

Plate 2.

This plate shows the general direction of ice movement in the last glacial epoch, as recorded by the striæ. The directions are necessarily generalized, and the local deflections due to the more prominent topographic features are not adequately represented. The arrows are in the positions of recorded striæ, though they represent but a small proportion of those which have actually been observed. The heavy line represents the approximate position of the moraine.

Plate 3.

Figure 1.—Is a section from a point on the Millstone river, above Griggstown, to Pine hill (a mile northeast of Perrineville) and beyond. It is essentially in the direction of the dip of the strata involved. It shows the disposition of the post-Cretaceous formations and their relations both to the older formations and to each other. The section especially shows the great amount of erosion which took place after the deposition of the Beacon Hill formation before the Pensauken was laid down. It likewise shows the relation of the Pensauken to the Jamesburg, as well as the amount of erosion which intervened between them.

Figure 2.—Is a cross section from Arney's Mount to Pine hill approximately in the direction of the strike of the several formations. The relation of the Beacon Hill, Pensauken and Jamesburg formations to each other and to the older formations are shown.

Figure 3.—Is a section from Rancocas creek to Crosswick's creek, approximately along the line between the villages of the same names. The section illustrates especially the peneplain character of the Cretaceous surface on which the Pensauken formation was deposited, and by inference, the great amount of erosion which followed the deposition of the Beacon Hill formation before the deposition of the Pensauken.

PLATE I.

PLATE II.

PLATE III.

PLATE IV.

PART II.

REPORT ON
ARTESIAN WELLS
IN
SOUTHERN NEW JERSEY.

BY

LEWIS WOOLMAN.

ARTESIAN WELLS IN SOUTHERN NEW JERSEY.

BY LEWIS WOOLMAN.

INTRODUCTION.

Commencing with and including the year 1889, the writer has contributed to each successive annual report papers concerning the development of artesian wells in southern New Jersey, and showing the persistent extension, one beneath the other, of various water-bearing horizons. The facts thus presented have abundantly demonstrated that water may with certainty be obtained by artesian borings at any locality within this portion of the State. While there have been a few failures, and in fact very few in comparison with the entire number of such wells put down, the writer is convinced that in nearly every case such failure has been due, not to absence of water-bearing strata, but to other causes, such as the passing and shutting off of the water-producing horizons, the collapsing of the casing or some other mechanical mishap, while in some cases discouragement has caused the discontinuance and abandonment of the work just before reaching the water-yielding sands.

The various wells are comprised in three groups:

1. Those associated with Miocene strata—these are necessarily located upon the ocean side of the State, but may cover a wide belt, which reaches inland along the railways from Atlantic City as far as the neighborhood of Winslow, if not farther.

2. Those associated with Cretaceous strata—these are located along a belt fifteen to twenty miles wide, bordering the Delaware river, and also bordering on the east a line extending from Trenton to Woodbridge, N. J. Wells so located cannot possibly draw from Miocene

horizons because Miocene deposits are mostly entirely absent from this belt, while on the contrary wells within the Miocene region may be continued entirely through such Miocene deposits and reach water-bearing sands within the underlying Cretaceous.

3. For convenience we classify under a third division wells in strata, both newer and older than those in which the wells of the two previously-defined groups are bored.

The wells in the newer strata draw from the Pleistocene or other Quaternary sands and gravels that rest nearly horizontally upon the beveled edges of the more steeply-dipping Miocene and Cretaceous beds, while those in the older strata obtain their supply either from the Triassic rocks or from the much older crystalline rocks.

The Pleistocene beds being mainly superficial, wells therein may be found located anywhere in the area under consideration. The wells, however, now reported in the older solidified rock deposits are situated either on the western margin of the Cretaceous belt, or a short distance beyond its border.

It may be here stated that no mention is made in the above classification of the Eocene, which certainly exists between the Miocene and the Cretaceous in this State, but we have no artesian well to report at this time that draws from beds of this age.

Wells belonging to the first and second classes, if located upon ground not more than ten feet or thereabouts above sea-level, will generally overflow, or if situated upon higher ground, the water will rise to ten feet or more above tide. In some cases, however, the rise is considerably more, as in the region about Marlton, where it averages at least fifty feet above sea-level.

The details of wells published at this time emphasize the persistent extension of three of the most important water horizons of southern New Jersey, viz., one in Miocene strata some distance beneath the great 300 to 400-foot diatomaceous clay bed, and having a thickness of about sixty feet, one in Cretaceous strata, beneath the Middle Marl bed, from which it is separated by a crust, only a few feet thick, which contains belemnites and shells of the Gryphea, an extinct oyster. This horizon has a thickness, at least in Salem county, of about eighty feet, and has probably a similar thickness in Cumberland county. The other horizon is at the base of the Cretaceous deposits, and, in fact, at the base of the entire series of the coastal plain sediments in New Jersey. It consists of a very coarse quartzose

gravel, often containing large cobbles. The thickness of this deposit has not yet been determined, but it holds an abundance of water.

It should be here stated that previous annual reports have demonstrated the occurrence of another valuable artesian horizon intermediate between the last two horizons named, viz., at the base of the Lower Marl bed. This horizon supplies wells at Freehold, Red Bank and Rumson's Neck, and also a number of wells at Asbury Park and Ocean Grove.*

There are, therefore, four marked water horizons beneath southern New Jersey, each of which is capable of furnishing a large quantity of water.

There has also been noted by the author in the Annual Report for 1892 five other water horizons higher than the four above named. These five horizons are either interbedded in or are closely associated with the Miocene diatom clay bed. Most of these higher horizons furnish but little water, as compared with the four lower ones defined above. The two lowest of these upper horizons will probably answer, and do now in some cases answer, the requirements for water-supply beneath the beaches where the amount needed is not large, while inland all of the five may possibly be utilized for a moderate supply. In fact, inland there are reasons why some of these horizons may be expected to yield a greater, and perhaps a considerably greater, amount of water.

The following shows in order the stratigraphical position of each of the minor and the principal water horizons:

	MINOR WATER HORIZONS.	
No. 1.	In sands about 75 feet above the great diatom bed	In Miocene Strata.
2.	In sands immediately beneath the top of the great diatom bed	
3.	In sands near the middle of the great diatom bed	
4.	In sands near the base of the great diatom bed	
5.	In sands immediately below the great diatom bed	
	GREATER OR PRINCIPAL WATER HORIZONS.	
No. 6.	In a 60-foot sand bed about 100 feet beneath the great diatom bed	
7.	In an 80-foot sand bed beneath the Middle Marl	In Cretaceous Strata.
8.	In a sand beneath the Lower Marl	
9.	In a heavy gravel at or beneath the base of the Plastic Clays	

*Many dug wells in eastern Monmouth county also get excellent water in this sand bed.

For more information respecting the first five horizons, the especially-interested reader is referred to the report for 1892, pages 298 to 301.

We now present, in the order above named, details respecting the wells belonging to each of the three groups under the following headings:

Artesian wells in Miocene strata.

Artesian wells in Cretaceous strata.

Supplement to report on artesian wells.

Under the latter title, besides the wells belonging to the third group, there are also included reports upon a few wells in and near New York City and Brooklyn and at one locality in Connecticut. These are published, because being contiguous to the State of New Jersey, they have in consequence a bearing upon its geology, both economic and otherwise.

A few of the wells herein noticed were sunk previous to the year covered by this report, but the records are introduced either because such records have not previously been printed, or, if so, there are recently-ascertained facts to publish.

ARTESIAN WELLS IN MIOCENE STRATA.

Numerous wells in Miocene strata have been published in past annual reports. We have, however, to notice in this report but four wells in beds of that age—these are located at Cape May Point, Wildwood and Atlantic City, N. J., and at Crisfield, Md. An account of the well at the last-named locality is introduced because its record is essential to the revelation of geological structure in New Jersey. The well at Cape May Point was noticed some years ago in these reports, and is now again referred to because of some new facts. The well at Wildwood presents the most important section that has been revealed by boring since the completion of the deepest of the wells put down at Atlantic City (1,398 feet), and reported in the year 1889. For this reason, this well at Wildwood is noticed at considerable length and with much minuteness of detail, and is illustrated with a carefully-prepared and accurate vertical section and a plate of certain microscopic fossils found in the borings. There is also introduced a skeleton vertical section, showing the relation and correspondence of the beds here passed through, with those penetrated at Atlantic City.

For comparison, there is also inserted a similar section of the well at Crisfield, Md., showing, likewise, considerable correspondence. In fact, the borings at Crisfield (1,140 feet), at Wildwood (1,244 feet) and at Atlantic City (1,398 feet), present important and typical sections of the Miocene strata of the Atlantic coastal plain.

The well herein reported at Atlantic City is the tenth successful artesian well that has been sunk at that resort.*

ARTESIAN WELL AT CAPE MAY POINT.

An unsuccessful boring to the depth of 456 feet was made at Cape May Point, and recorded by Prof. G. H. Cook in the annual report for 1885, page 140. It is now again noticed because of geological facts that have been recently learned respecting it. This well was visited by the writer a year or two after it was put down and before the drillings therefrom had been cleared away. On turning over the dump a considerable number of fossil shells were obtained.

The well was sunk by the use of the drill and sand pump—a method which furnishes specimens of the strata unmixed and more nearly in their natural condition than either of the hydraulic processes very often employed.

Specimens from this well were placed at the time in the collections of the Survey, and are now preserved in the State museum.

The specimens, both those in the museum and those obtained on the spot by the writer, have recently been examined, both macroscopically and microscopically, with the following result:

Specimens as marked	Character.	Notes.
Near the surface	Sand and sandy clay	Fossil diatoms and sponge spicules.
No. 1.	Gray sand	Cœcum and sponge spicules.
2.	Yellowish sand	Sponge spicules and a few diatoms.
3.	Gray sand	Cœcum.
4.	" "	
320 to 360 feet, *a*	Gray sand	A few diatoms.
" " *b*	" "	Shells, St. Mary's fauna. (See notes below.)
" " *c*	" "	
" " *d*	" clay.	
" " *e*	" sand.	
" " *f*	" clay.	

*As this goes to print, the boring of the eleventh well at this locality had just been completed, the depth being 809 feet.

The depths, as may be observed, were not marked on the specimens above 320 feet. Prof. Cook states that "the first 270 feet were in beach sand, when thin beds of clay began to be found in the sand," and that "from 320 to 360 feet many broken shells were met with." No specimens of the borings below 360 feet are found in the museum, though a depth of 456 feet was reached, as before stated. The shells obtained by the writer undoubtedly came from the horizon of 320 to 360 feet. They are as follows:

Crepidula sp.? fragments.
Cardium sp.? fragments.
Venus mercenaria Linn.
*Mactra modicella Conrad, young.
Arca sp.?
Pecten sp.?
Lucina crènulata Conrad.
Melanopsis Marylandica Conrad.
Nassa (Tritia) trivittata Say.
Solen fragment.
Eulima sp.?
Turritella plebeia Say.
Turritella variabilis Conrad.
*Pleurotoma limulata Conrad.
*Terebra inornata Whitfield.
*Terebra simplex Conrad.
*Ptychosalpinx, probably Multirugata Conrad.
*Corbula, probably nasuta Say.
*Cœcum glabrum Mont.
Trochita sp.?
Barnacles = Balanus.

The specimens marked with an asterisk (*) were identified by Dr. W. H. Dall, who states that "the horizon of nearly all these species is that of St. Mary's county, Maryland, of the Chesapeake Miocene."

In the identification of the remaining forms the assistance of Prof. Angelo Heilprin was had.

By far the most numerous of all the molluscs was the Melanopsis of a species which is especially characteristic of the St. Mary's bed. This same specific form of Melanopsis has been again discovered the present year at a little greater depth in a well put down at Wildwood on Five-Mile Beach. See page 173.

A workman was recently seen who assisted in boring the first 270 feet of this well, and who says that, at that depth, they were in a white, marly clay, with green lumps in it; that mud was found at the depth of twelve feet, salt water at thirty-five feet and wood at 125 feet. The depth of 270 feet probably marks the top of the Miocene.

From the sands and clays around the mouth of the well there were extracted a considerable number of diatoms.

ARTESIAN WELL AT WILDWOOD, N. J.

Its Geology and Paleontology.

Coarse gravel at	215 feet and at 309 feet.	
Four diatomaceous clay beds.		
Three Miocene fossil molluscan horizons.		
Ear bones of fishes (Otoliths).		
Diatoms, sponge spicules, foraminifera, coccoliths and coral.		
Eocene (?) Greensand Bed	1,104 to 1,245 feet.	
Ten thin bands of rock strata.		
Elevation of surface	8	"
Fresh water flowing 7 feet above the surface at	887	"
Salt water flowing above the surface at	1,085	"
Total depth attained by boring	1,244	"

In the annual report for last year (1893), pages 399 to 401, appeared a notice of a well at Wildwood, on Holly Beach, about seven miles north of Cape May. That well reached a depth of 215 feet, but as water of satisfactory quality was not found another well was drilled the present year, the work being contracted for by Uriah White, whose superintendent in charge of the work, and by his instructions, courteously furnished a full series of specimens of the various sands, gravels, clays and marls penetrated, together with complete notes respecting the same. The boring reached a total depth of 1,244 feet.

A strong overflow of water occurred at the depth of 1,185 feet, which, however, was quite salty; for this reason the well was finally finished with a depth of but 931 feet, drawing a supply of fresh water from a sand bed about forty feet in thickness next below the depth of 887 feet. The water flows over the surface, and will rise above it seven feet. The elevation of the ground is about eight feet above tide.

The well was cased with an 8-inch iron pipe to ninety-eight feet, and then with a 6-inch pipe to 519 feet. A 4½-inch pipe was then introduced and continued to 793 feet, after which a 3-inch pipe was sunk to the depth of 1,004 feet. The boring was prospected beyond this without being cased.

We here insert a columnar section drawn to scale. On the left is a detailed record and description of strata, in which the minutest beds are shown. On the right these strata are grouped into larger divisions, having certain broad characteristics, the fossiliferous and other geological features of which are noted.

The salient facts learned from a careful study of the preceding

section, and an examination of the borings both with the microscope and with the unaided eye, are the occurrence of two rather coarse gravel horizons just at or below the depths of 215 and 309 feet, four beds of diatomaceous clays, three noticeable horizons containing Miocene fossils, mainly molluscan, and a bed of green sand, probably Eocene in age, beginning at the depth of 1,104 feet, and continuing to the base of the boring.

Both the diatoms and the molluscs throw light upon the ages of the strata penetrated. The diatomaceous beds will be first considered, after which the facts respecting the gravel horizons, the molluscan strata and the greensand bed will be noted, including also lists of fossils, both microscopic and otherwise.

DIATOMACEOUS CLAY BEDS.

The first or uppermost diatomaceous bed is seventeen feet thick, and occurs between the depths of twenty-nine and forty-six feet. The diatoms in this bed are exclusively marine.

The second diatomaceous bed is about 100 feet thick, and is found between the depths of 78 and 181 feet. The peculiarity of this bed is that both marine and fresh-water diatoms are intermingled therein, the fresh-water forms presenting an unusually large number of species and preponderating in individual numbers over the marine.

The third bed is over 400 feet thick, and occupies the interval between the depths of 370 and 793 feet. The diatoms are exclusively marine.

The fourth diatom bed is probably not over twenty feet thick, and occurs between the depths of 1,040 and 1,060 feet.

These four beds will now be separately treated, and the features peculiar to each pointed out in detail, commencing with the uppermost.

Diatom bed No. 1.—The uppermost bed extends from the depth of twenty-nine feet to that of forty-six feet, and represents geologically a very recent marine mud or clay. This bed seems, so far as our present knowledge indicates, to underlie that portion of the ocean border of the State that has a low altitude, one which does not exceed about forty-five feet above tide. It is found at tide-level, or a few feet below at Absecon, Belmar and Long Branch. Inland it gradually rises above sea-level, and is so found at Mays Landing, Bridgeton and Buckshutem, below Millville.

Elsewhere beneath the beaches it has been found in the borings from Ocean City, Longport, Atlantic City and Beach Haven, at depths varying according to locality from forty to seventy feet. It is generally overlain by coarse gravels, which frequently contain fossiliferous pebbles.*

The estimated dip of this bed as made by the author from data in his hands is about six feet per mile.

This bed can be recognized wherever found by the special assemblage of diatoms which it contains, and which collectively differ from those associated together in either of the underlying beds. One specific form *Triceratium favus* (see Plate VI.), and which also occurs in the second or next lower bed, may be considered not only as characteristic of these beds, but also as indicative of their recent age, since this diatom is found in the bed now under consideration at each of the localities above named, while it does not occur in the two lowest beds (the third and fourth at this place), nor elsewhere in the Miocene diatomaceous deposits of the Atlantic coastal plain, of which these two lowest beds form a part. This *Triceratium* is also found living along the coast and in the Delaware river as far inland as Philadelphia. It is also now being deposited in the marshes bordering the same river up to about the same latitude.†

Diatom bed No. 2.—The second diatomaceous bed, that at 78 to 181 feet in depth, does not exist beneath the beaches to the northward, if we may judge by the specimens of borings obtained from various

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*These gravels have been directly derived from a working over and redepositing of the gravels occupying the higher ground to the westward. The fossils contained in the pebbles show that originally, however, they were derived from Silurian and Devonian rocks. Fossiliferous bed rocks of these ages are not now known eastward or southward of the Kittatinny mountain.

† Probably to be correlated in age with this deposit, is a bed of clay likewise containing diatoms that underlies that portion of Philadelphia having an elevation ranging from twenty-five to forty feet, but not higher. At Philadelphia, however, the forms are mixed, being both marine and fresh-water in species. At that time the Delaware bay, with its saline influence, probably extended up to the city, thus accounting for the presence of the marine diatoms, while the combined influx of the two great fresh-water rivers, the Delaware and the Schylkill, whose junction then must have been just below Fairmount, favored the introduction of the fresh-water forms. This portion of Philadelphia may be defined as the area occupied by what is locally known as the old city proper, and which, at that time, was probably a swampy meadow land, similar in character to the marshes now in process of forming still farther southward at and above League island, between the present junction of the two rivers.

wells or by the records when no specimens were procured. It probably extends only locally in Cape May county.

This bed, like the one just described and which overlies it, is geologically recent, as is evidenced by the assemblage of diatoms, especially the marine ones.

Triceratium favus, before named, occurs in this bed, but, as already stated, it does not occur in the two underlying Miocene beds.

The large preponderance of the fresh-water diatoms over the marine indicates the proximity at the time this deposit was laid down of a very considerable fresh-water influence, such as could not have been furnished by any stream now in existence in this region except the Delaware. This bed is probably associated with the delta of that river in a somewhat recently-past geological time and before the present peninsula of Cape May was formed.

A diatomist who has examined this deposit writes to the author (perhaps rather enthusiastically) that besides the marine forms "it contains almost every known fresh-water species." One of the fresh-water specific forms is unique. It resembles a diatom heretofore known only from New Zealand, and which occurs there, living in fresh or slightly-brackish waters.

The form in New Zealand was named *Triceratium trifoliatum* by Cleve, and on page 401 of last year's report the form here found was referred to that species. A number of diatomists consider, however, that the generic name is wrongly given, while C. S. Boyer, an authority upon diatoms, is of the opinion that the form occurring on this bed presents sufficient variation from its New Zealand relative to entitle it to a new specific nomenclature. He has accordingly named it *Hydrosera* (*Terpsinæ?*) *Novæ Cæsareæ* (see Plate VI.), the New Zealand form becoming *Hydrosera trifoliata.**

* The occurrence of this *Hydrosera* in the Wildwood borings was first observed by C. L. Peticolas, who called the writer's attention to it in a letter dated September 9th, 1893, under the name of *Triceratium trifoliatum*.

In the Transactions of the New York Academy of Sciences, May 28th, 1894, Heinrich Reis notices a fresh-water diatomaceous stratum immediately beneath the deposits of the terminal moraine, along the northern shore of Long Island, on Lloyd's Neck and near Cold Spring. Included in the list of species therefrom he figures a form under the name of *Triceratium trifoliatum*, of which he says but two specimens were seen. His figure, in outline and otherwise, seems identical with our *Hydrosera* except that no central punctæ are shown.

A comparison of our *Hydrosera* with the original figure of *Triceratium trifoliatum* of Grove and Sturtin shows considerable difference, both in outline and in the arrangement and extent of the surface-markings or punctæ.

The occurrence of another species, *Polymyxus coronalis*, in this bed, is also unique, since it has heretofore only been known from the mouths of the Para and the Amazon, where it now lives directly under the equator, subject to much warmer climatal conditions than at present prevail in New Jersey.

C. S. Boyer says it is certain that this diatom does not now exist along the coast of the United States, and suggests the possibility of the prevalence of a different climate in this latitude at the time this bed was put down.

Both to the geologist and the diatomist this is a remarkably interesting and unique bed.

Three cleanings of the diatoms in this bed, from the matrix containing them, have been separately made for the writer by C. L. Peticolas, C. S. Boyer and John A. Schulze. All of these cleanings showed the two unique forms mentioned.

C. L. Peticolas has also established as a new species another diatom closely allied to *Surirella gemma* under the title of "*Surirella Woolmaniana.*"

C. S. Boyer has published in the Bulletin of the Torrey Botanical Club the following 152 species from this bed, and says that eighty of these are exclusively fresh-water forms, and forty-seven exclusively marine, while twenty-five inhabit either fresh and brackish, or brackish and marine waters.

It may be remarked, however, that the preponderance in individual numbers of the fresh-water diatoms over the marine is greater than the above figures would indicate.

MARINE AND FRESH-WATER DIATOMS FROM A UNIQUE BED BETWEEN THE DEPTHS OF 78 AND 181 FEET, AT WILDWOOD, N. J., AS IDENTIFIED BY CHARLES S. BOYER, A.M.

Achnanthes Hudsonis Grun.
A. inflata (Kütz.) Grun.
A. subsessilis Ehr.
Actinocyclus Ehrenbergii Ralfs.
A. subtilis Greg.
Actinoptychus heliopelta Grun. forma minor. Only one specimen has been noticed.
A. undulatus Ehr.
A. vulgaris Schum.
Amphora ovalis (Bréb.) Kütz. var. *gracilis* (Ehr.) V. H.
Aulacodiscus Argus Ehr.
Auliscus pruinosus Bail.
Biddulphia Rhombus Wm. Sm.
Brebissonia Boeckii (Kütz.) Grun.
Campylodiscus echeneis Ehr.
Cerataulus lævis Roper.
Cocconeis placentula Ehr.
Coscinodiscus Argus Ehr.

C. excentricus Ehr.
C. fasciculatus A. Schm.
C. marginatus Ehr.
C. minor Ehr.
C. nitidulus Greg.
C. Oculus-Iridis Ehr.
C. radiatus Ehr.
C. subtilis Ehr.
Cyclotella Kützingiana Thw.
Cymbella affinis Kütz.
C. cistula (Hempr.) Kirchn.
C. cuspidata Kütz.
C. cymbiformis Ehr.
C. Ehrenbergii Kütz.
C. gastroides Kütz.
C. lanceolata (Ehr.) Kirchn.
C. tumida (Bréb.) V. H.
Encyonema ventricosum Kütz.
Cystopleura (*Epithemia*) *Argus* (Ehr.) Kunze. An abnormal form with flexuose outline has been noticed.
C. gibba (Ehr.) Kunze.
C. gibberula (Ehr. ?) Kunze.
C. Musculus (Kütz.) Kunze.
C. Musculus constricta (Bréb.) V. H.
C. Sorex (Kütz.) Kunze.
C. Zebra (Ehr.) Kunze.
Eunotia Arcus Ehr.
E. diodon Ehr.
E. impressa Ehr.
E. major (W. Sm.) Rab.
E. parallela Ehr.
E. pectinalis (Dillw. ?) Rab.
E. prœrupta Ehr.
E. robusta Ralfs.
E. tetraodon Ehr.
E. triodon Ehr.
Gomphonema acuminatum coronatum Ehr.
G. Augur Ehr.
G. capitatum Ralfs.
G. geminatum (Lyngb.) Ag.
G. gracile Ehr.
G. lanceolatum Kütz.
G. olivaceum (Lyngb.) Kütz.
G. turgidum Ehr.
G. Vibrio Ehr.
Hyalodiscus stelliger Bail.
H. subtilis Bail.

HYDROSERA (TERPSINŒ?) NOVÆ-CÆSAREÆ Boyer, n. sp.* (See Plate VI.)

Melosira granulata (Ehr.) Ralfs.
Navicula acrosphœria Rab.
N. affinis Ehr.
N. Americana Ehr.
N. bicapitata Lagerst.
N. Bombus (Ehr.) Kütz.
N. Brebissonii Kütz.
N. columnaris Ehr.
N. Crabro (Ehr.) Kütz.
N. Dactylus Ehr.
N. Dariana A. Schm.
N. decurrens Kütz.
N. distans (W. Sm.) Ralfs.
N. elliptica Kütz.
N. Fischeri A. Schm.
N. formosa Greg.
N. gibba Ehr.
N. Hitchcockii Ehr.
N. humerosa Bréb.
N. Iridis amphirhyncus Ehr.
N. Kamorthensis Grun.
N. latissima Greg.
N. Lewisiana Grev.
N. Liber linearis (Grun.) V. H.
N. limosa Kütz.
N. Lyra Ehr.
N. major Kütz.
N. mesolepta Ehr.
N. mesolepta nodosa Ehr.
N. mesostyla Ehr.
N. nobilis (Ehr.) Kütz.
N. pachyptera Kütz.
N. permagna (Bail.) Edw.
N. peregrina (Ehr. ?) Kütz.
N. placentula (Ehr.) Kütz.
N. polyonca Bréb.
N. pusilla W. Sm.
N. rhomboides Ehr.
N. sphœrophora Kütz.
N. Smithii Bréb.
N. stauroptera parva Grun.
N. tabellaria Kütz.
N. termitina Ehr.
N. trinodis inflata Schultze.
N. viridis (Nitzsch) Kütz.
Nitzschia Campeachiana Grun.

*Bulletin of the Torrey Botanical Club, Vol. XXII., page 268.

N. cirumsuta (Bail.) Grun.
N. granulata Grun.
N. salinarum Grun.
N. scalaris (Ehr.?) W. Sm.
N. Sigma (Kütz), W. Sm.
N. tryblionella maxima Grun.
Odontidium mutabile genuinum Grun.
Plagiogramma tesselatum Grev., rare.
Pleurosigma eximium (Thw.) Grun. and Cl.
P. Sciotœnse Sulliv.
P. Spencerii (Quek.) W. Sm.
Polymyxus coronalis L. W. Bail.
Pseudauliscus radiatus Bail.
Pseudœunotia flexuosa (Bréb.) Grun.
Rhaphoneis amphiceros Ehr.
R. Belgica Grun.
R. gemmifera Ehr.
R. Rhombus Ehr.
Stauroneis acuta W. Sm.
S. gracilis Ehr.
S. Phœnicenteron Ehr.
Surirella angusta Kütz.
S. biseriata (Ehr.) Bréb.
S. cruciata A. Schm.
S. crumena Bréb.
S. elegans Ehr.
S. Febigerii Lewis.
S. oblonga Ehr.
S. ovalis Bréb.
S. ovalis ovata (Kütz.) V. H.
S. splendida Ehr.
S. striatula Turp.
S. tenera Greg.

SURIRELLA WOOLMANIANA Peticolas, n. sp.*

Synedra delicatissima W. Sm.
S. investiens W. Sm.
Terpsinœ Americana (Bail.) Ralfs.
Tetracyclus emarginatus (Ehr.) W. Sm.
T. lacustris Ralfs.
Triceratium alternans Bail.
T. favus Ehr.
T. sculptum Shadb.

In addition to the forms above listed, Dr. D. B. Ward calls attention in a letter recently received to another seen by him in this bed, viz., *Navicula Delawarensis* Grunow, which he says "is a recently-discovered form stated by Cleve to be now living in the mouth of the Delaware river and along the Connecticut shore." Dr. Ward also says it occurs sparingly at the latter locality, but "abundantly in a semi-fossil state in some brackish-water peat along the Hudson river in the vicinity of Poughkeepsie, N. Y."

Diatom bed No. 3.—The third bed above enumerated as containing diatoms, is one of the most remarkable and also most extensive diatomaceous beds in the world. It has been traced by means of outcrops from Asbury Park, N. J., to the Virginia-North Carolina border, south of Petersburg, underlying the entire coastal plain east of the line of outcrops. This is further proven by its occurrence in well-borings at the following localities, viz.:

1. ALONG THE COAST.

At Asbury Park, N. J.,	between the depths	of	16 feet	and	94 feet.
" Barnegat,	"	at	"	"	" 120 feet.			
" Beach Haven,	"	between	"	"	" 290 feet	and	543 feet.	
" Atlantic City,	"	"	"	"	" 380	"	670	"
" Ocean City,	"	"	"	"	" 370	"	680	"

*Bulletin of the Torrey Botanical Club, Vol. XXII., page 265.

2. INLAND.

At Wildwood, N. J.,	between	the depths	of	370 feet and 793 feet.
" Pleasant Mills, N. J.,	at	the depth	of	45 feet.
" Weymouth,	"	" "	"	"	40 "
" May's Landing,	"	between	"	"	54 and 176 feet.
" Port Norris,	"	at the	"	"	200 feet.
" Clayton, Del.,	between	"	"	"	100 feet and 150 feet.
" Cambridge, Md.,	"	"	"	"	192 " " 335 "
" Crisfield,	" "	"	"	"	365 " " 771 "

The outcrops either of this bed, or of the fourth bed, as known at Wildwood, occur near Asbury Park and near Shiloh, N. J., at Brentford, Del., and at Claiborne, Md.; also along the shores of the Chesapeake from Fair Haven southward; along the Patuxent from the vicinity of Lyons creek and Nottingham, southward; along the Potomac upon the north side at Pope's creek, and upon the south side in Nomini Cliffs. It is also found outcropping along all the eastward-flowing streams in Virginia as far southward as the Meherrin river, where that stream crosses from the last-named State into North Carolina, nearly south of Richmond and Petersburg. The bed probably extends farther southward. Its length, so far as now known, is about 300 miles, while its maximum thickness, as shown by the above table, is fully 400 feet.

At Wildwood, as noticed above, it occupies the interval between the depths of 370 and 793 feet. Specimens of the borings were taken every twenty feet or thereabouts, and carefully examined under the microscope. Marine diatoms were revealed in almost every instance, sometimes only sparingly and again very abundantly. The diatoms were absent where the strata were sands or gravels—they were less numerous in sandy clays and more numerous in fine and nearly pure clays. The decided molluscan horizons were generally in the coarser deposits. The following are the author's notes made at the time of of the examination:

Specimens.	
370 feet to 389 feet.	Bluish clay, a few marine diatoms, plenty of comminuted shell.
399 " " 409 "	" " " " " " "
409 " " 428 "	" sand and gravel, plenty of molluscan fossils.
428 " " 448 "	" clay, diatoms.
448 " " 468 "	" " " and sponge spicules.
468 " " 487 "	" " " " "
487 " " 509 "	" " " " "
509 " " 528 "	" " very rich.
528 " " 535 "	" "

Specimens.	
535 feet to 554 feet.	Bluish clay, a few sponge spicules, no diatoms seen.
554 " " 566 "	" " " " " "
566 " " 586 "	" " sponge spicules and a few pyritized diatoms.
586 " " 607 "	" " diatoms, a few.
607 " " 627 "	" " " "
627 " " 617 "	" " very sandy, a few sponge spicules.
655 " " 675 "	Brownish clay, diatoms and sponge spicules.
675 " " 694 "	" " " " "
694 " " 713 "	Lighter-colored clay, diatoms and sponge spicules.
713 " " 720 "	Brownish clay, sand and molluscan fossils, no diatoms.
720 " " 732 "	Dark-brown clay, a few diatoms, clay very sandy.
732 " " 744 "	" " " " " comminuted shells plenty.
744 " " 764 "	Bluish clay, diatoms, shells plenty at 750 feet.
764 " " 784 "	" " "
784 " " 793 "	" " "

Separate cleanings of the diatoms from this division were made for the writer by C. L. Peticolas from specimens covering each of the following intervals: 370 to 448 feet, 528 to 535 feet, 732 to 744 feet, and 744 to 793 feet. Time and circumstances have not permitted the listing of the species found in these cleanings, but nearly if not quite all the characteristic and other associated forms that have been found in the same bed at Atlantic City have been seen here.

The specific forms obtained at Atlantic City have been identified by C. Henry Kain and E. A. Schultze. The list, which includes a number of new species, was first published by them in the Bulletin of the Torrey Botanical Club,* the new species being also figured therein. This list, slightly revised, was afterward printed as part of another paper by the present writer in the proceedings of the Academy of Natural Sciences of Philadelphia.† This list is introduced below as rendering this paper more complete:

The forms from the richest portions at Atlantic City at the depths of 400, 525 and 625 feet, were most carefully observed under the microscope and identified.

There are determined 149 species, which are distributed among 49 genera. There will probably, however, be a few forms yet to add. Forms marked rare are of rare occurrence in the well and not necessarily so elsewhere.

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*Vol. XVI., pp. 71 to 76, and pp. 207 to 210; Plates LXXXIX., XCII., and XCIII.

† Proceedings 1890, pages 136 to 140.

DIATOMS FROM THE GREAT 400-FOOT MARINE MIOCENE DIATOMACEOUS BED OF THE ATLANTIC COASTAL PLAIN, AS IDENTIFIED BY C HENRY KAIN IN BORINGS FROM ATLANTIC CITY, N. J.

Actinocyclus Ehrenbergii Ralfs.
Actinocyclus subtilis (Grev.) Ralfs.
Actinocyclus interpunctatus Bright. Rare.
Actinocyclus Ralfsii W. Sm.
Actinodiscus Atlanticus, n. sp, Kain & Schultze.
Actinoptychus areolatus Ehr.
Actinoptychus Grundleri A. S.
Actinoptychus splendens (Ehr.) Grun.
Actinoptychus undulatus Ehr., var. *Halionyx* Grun. Several varieties.
Actinoptychus vulgaris Schuman, var. *Virginica* Grun. Several varieties.
Amphitetras minuta Grev. Rare.
Anaulus birostratus Grun. Very rare.
Asterolampra Marylandica Ehr.
Aulacodiscus Crux Ehr. Two varieties.
Aulacodiscus Petersii Ehr.
Aulacodiscus Sollittianus Norman.
Auliscus Caballi A. S.
Auliscus cœlatus Bailey.
Auliscus pruinosus Bailey.
Auliscus (*Glyphodiscus?*) *spinosus* Christian.
Biddulphia aurita (Lyngb.) Breb.
Biddulphia alternans Christian.
Biddulphia Baileyi W. Sm
Biddulphia Brittoniana, n. sp., Kain & Schultze.
Biddulphia Cookiana, n. sp., Kain & Schultze.
Biddulphia Woolmanii, n. sp., Kain & Schultze.
Biddulphia decipiens Grun. Rare.
Biddulphia elegantula Grev.
Biddulphia pulchella Gray. Rare.
Biddulphia rhombus (Ehr.) W. Sm.
Biddulphia seticulosa Grun.
Biddulphia Tuomeyi Bailey.
Biddulphia turgida (Ehr.) W. Sm.
Biddulphia longispina Grun.
Biddulphia Weissflogii Grun.
Cerataulus (*Californicus?* var.), n. sp., Kain & Schultze.
Cocconema lanceolatum Ehr. Rare.
Coscinodiscus Argus Ehr.
Coscinodiscus Asteromphalus Ehr.
Coscinodiscus concavus Ehr.
Coscinodiscus eccentricus Ehr.
Coscinodiscus elongatus Grun.
Coscinodiscus excavatus Grev. Several varieties.
Coscinodiscus gigas Ehr.
Coscinodiscus isoporus Ehr.
Coscinodiscus Lewisianus Grev. Rare.
Coscinodiscus lineatus Ehr.
Coscinodiscus Nottinghamensis Grun. Rare.
Coscinodiscus Oculus Iridis Ehr.
Coscinodiscus perforatus Ehr.
Coscinodiscus radiatus Ehr.
Coscinodiscus rhombicus Castracane.
Coscinodiscus robustus Grev.
Coscinodiscus senarius A. S.
Coscinodiscus symmetricus Grev.
Cestodiscus ovalis Grev.
Cestodiscus rhombicus Grev.
Chætoceros (*didymus?* Ehr.)
Craspedodiscus coscinodiscus Ehr.
Craspedodiscus coscinodiscus, var. *Nankoorensis*, Grun.
Cyclotella operculata Kütz.
Cymatopleura solea W. Sm.
Dicladia capreolus Ehr.
Discoplea physoplea Ehr.
Dimeregramma Nova Cæsarea, n. sp., Kain & Schultze.
Dimeregramma Nova Cæsarea var. *obtusa*, n. var., Kain & Schultze.
Dimeregramma fulvum (Greg) Ralfs.
Epithemia Gibba (Ehr.) Kütz. Rare.
Ethmodiscus? sp.? Castracane.
Eucampia Virginica Grun. Rare.
Eunotia monodon Ehr. Two varieties.
Eunotia robusta (Ehr.) Ralfs. Several varieties.
Eunotia Americana, n. sp., Kain & Schultze.

Eupodiscus Argus Ehr.
Eupodiscus radiatus Bailey.
Eupodiscus Rogersii Ehr. Varieties with 3, 4 and 5 processes.
Eupodiscus sp.?
Goniothecium obtusum Ehr.
Goniothecium odontella Ehr.
Goniothecium Rogersii Ehr.
Grammatophora serpentina Ehr. var. Rare.
Hemiaulus affinis Grun.
Hemiaulus bipons (Ehr.) Grun.
Hemiaulus polycistinorum Ehr.
Huttonia Reichardtii Grun. var.
Hyalodiscus lævis Ehr.
Hyalodiscus Stelliger Bailey. (*Podosira maculata* W. Sm.)
Liradiscus minutus Grev.
Mastogonia Actinotychus Ehr.
Melosira sulcata (Ehr.) Kütz.
Navicula crabro Ehr.
Navicula didyma Ehr.
Navicula De Wittiana Kain & Schultze.
Navicula elliptica Kütz.
Navicula entomon Ehr.
Navicula forcipata Grev.
Navicula gracilis (Ehr.) Kütz.
Navicula Hennedyi W. Sow.
Navicula Lewisiana Grev.
Navicula Lyra Ehr.
Navicula macilenta Ehr. Rare.
Navicula (pinnularia) major Kütz. Rare.
Navicula permagna Bail.
Navicula prœtexta Ehr.
Navicula Smithii Breb.
Navicula viridis Kütz. Rare.
Plagiogramma Gregorianum Grev.
Pleurosigma Virginiacum Peticolas.
Pleurosigma sp.? Fragments of a very large form allied to *P. angulatum.*
Psued-auliscus radiatus Bailey.
Pyxidicula cruciata Ehr.
Rhabdonema Atlanticum, n. sp., Kain & Schultze.
Raphidodiscus Febigerii T. Christian.
Rhaphoneis gemmifera Ehr.
Rhaphoneis amphiceros Ehr.
Rhaphoneis Belgica Grun.
Rhaphoneis fluminensis Grun.
Rhaphoneis scalaris Ehr.
Rhizosolenia Americana Ehr.
Rhizosolenia styliformis Bright.
Sceptroneis caduceus Ehr.
Sceptroneis gemmata Grun.
Stephanogonia Actinoptychus Ehr.
Stephanogonia polygona Ehr.
Stephanopyxis apiculata Ehr.
Stephanopyxis ferox (Grev.) Ralfs.
Stephanopyxis Corona (Ehr.) Grun.
Stephanopyxis Grunowii Grove & Sturt.
Stephanopyxis limbata Ehr. Rare.
Stephanopyxis Turris (Grev.) Ralfs.
Stictodiscus Buryanus Grev.
Stictodiscus Kittonianus Grev.
Surirella Febigerii Lewis.
Tabulina testudo J. Brun.
Terpsinœ intermedia Grun. var.
Triceratium Americanum Ralfs.
Triceratium condecorum Bright.
Triceratium Ehrenbergii Grun.
Triceratium Ehrenbergii (*Discoplea undulata* Ehr.)
Triceratium Fisherii A. S.
Triceratium Heilprinianum, n. sp., Kain & Schultze.
Triceratium Kainii, n. sp., Schultze.
Triceratium indentatum, n. sp., Kain & Schultze.
Triceratium Kainii Schultze, var. *constrictum* Kain & Schultze, n. var.
Triceratium Marylandicum Bright.
Triceratium obtusum Ehr.
Triceratium robustum Grev.
Triceratium semicirculare Bright. = (*Euodia Brightwellii* Ralfs.)
Triceratium spinosum Bailey.
Triceratium Solenoceros Ehr. Rare.
Triceratium tessellatum Grev.
Triceratium undulatum Ehr.
Tryblionella Hantzschiana Grun.
Tryblionella scutellum W. Sm.

Diatom bed No. 4.—The fourth and lowest diatom bed penetrated in this well is estimated to be probably about twenty feet in thickness. It occurs between the depths of 1,040 and 1,060 feet.

Most of the species above enumerated as having been found in the third bed occur also in this, with at least one additional form, *Actinoptychus Heliopelta* Grunow.

This is a notable and geologically characteristic form, and will be again referred to.

GENERAL REMARKS UPON THE DIATOMS FROM THE MIOCENE BEDS.

The species found in the third and the fourth diatom beds are almost exclusively marine, there being seen only occasionally a fresh-water form such as may have been carried to the deposit by currents from the neighboring fresh-water streams of that time. Both these beds contain a number of diatoms that are not found in either the first or the second beds, and, *vice versa*, they do not contain certain other diatoms which do occur in the two upper beds. Such forms in either case may be considered as characteristic of the bed in which they occur, and when seen in deposits from any other locality, at least along the Atlantic coast of the United States, they may be used in the identification and correlation of such deposits.

One of the distinguishing forms of the third bed is *Coscinodiscus excavatus* (see Plate VI.)—a fine, large, circular discoid diatom having in the center three and sometimes more elevations or excavations called processes that look somewhat like the reticulated eyes of insects. It has likewise been found in this bed elsewhere in borings from Beach Haven, Atlantic City, Mays Landing and Ocean City, N. J., and also in borings from Cambridge and Crisfield, Md., and from Fortress Monroe, Va.

Actinoptychus Heliopelta (see Plate VI.), the diatom already mentioned as having been found in this boring only from the fourth or lowest diatom bed, is like the *Coscinodiscus* just noted, also a beautiful large discoid form. It has a perfect star in the center, the points of the star varying somewhat in number in different specimens. Specifically it is appropriately named *Heliopelta,* which means sun shield.* Simply as *Heliopelta* it has long been endearingly

*Originally this diatom was generically named *Heliopelta,* by Ehrenberg, who gave to each specimen, showing a variation in the number of rays, a different specific name. As this form, however, clearly belongs to the previously-established genus, *Actinoptychus,* and as Ehrenberg's species are generally regarded only as varieties, Grunow has constituted Ehrenberg's generic name its specific name, and has likewise relegated his species to the grade of varieties only.

known to diatomists, who will probably continue to thus familiarly refer to it rather than by the more full and accurately-correct technical nomenclature given above.

This diatom is especially characteristic of the base, and the base only, of the Miocene diatomaceous clay deposits of the Atlantic coastal plain. Wherever it has so far been found, it always has this stratigraphical position. It so occurs in this well at the depth of 1,040 to 1,060 feet, and in borings at Asbury Park at the depth of forty to ninety feet; at Clayton, Del., at the depth of 100 to 150 feet, and at Crisfield, Md., at the depth of 780 feet.

In the same stratigraphical position it occurs in outcrops near Asbury Park, and near Shiloh, N. J.; also at Claiborne, eastern shore, Md.; at Nottingham and vicinity, western shore, Md., and at Petersburg and Bermuda Hundred, Va.

In the Nottingham region, within, but at the very base of the *Heliopelta* stratum, the writer has seen such characteristic Miocene Molluscan fossils as *Ecphora quadricostata* and *Pecten Humphreysii*, while not more than six inches lower could be seen some twenty feet or thereabouts of a greensand bed that has been referred to the Eocene by the United States geologists, which bed, if properly correlated, outcrops three miles northwest, at Marlboro, where the writer has collected such characteristic Eocene fossils as *Ostrea compressirostra* and *Turritella Mortoni*.

It has already been stated that this diatom occurs at the depth of 780 feet at Crisfield, Md. According to N. H. Darton, this depth marks the division between the base of this bed and the top of a bed seventy-five feet* thick, consisting of a dark olive-green argillaceous and glauconitic sand which he refers to the Pamunkey formation, *i. e.* the Eocene.

In this Wildwood well, a short distance below the *Heliopelta* horizon, namely, at the depth of 1,104 feet, we reach the top of a 140-foot bed of glauconitic greensand marl, probably the equivalent of the glauconitic sand at Crisfield. This bed will be noticed in detail farther on.

It is interesting thus to observe the occurrence of *Heliopelta* at the three localities of Wildwood, Crisfield and Nottingham, and that at each place it is either at or near the base of the Miocene and above the Eocene.

*The author makes this portion of the section at Crisfield 129 feet thick. See page 184. Also see Plate VII.

The general assemblage of forms found in these Miocene diatom beds is shown on a plate in the report for 1891. Fifty-six forms are figured thereon, or about one-fourth the number that has been observed in the entire bed at all its various localities.

We insert reproductions on Plate VI. of photographs made through the microscope of *Actinoptychus Heliopelta*, *Coscinodiscus excavatus* and *Triceratium favus*, and a similar reproduction of a drawing likewise made through the microscope of *Hydrosera* (*Terpsinœ?*) *Novœ Cœsareœ*. The *A. Heliopelta* are twice enlarged from the original negative. The numbers below each form indicate the linear enlargement, thus, 880 × means magnified 880 diameters.

We will now consider the two gravel strata, the three shell horizons and the greensand bed, taking them in the order of their occurrence from the top downward.

GRAVELS AT THE DEPTHS OF 200 TO 215 FEET AND 309 TO 328 FEET.

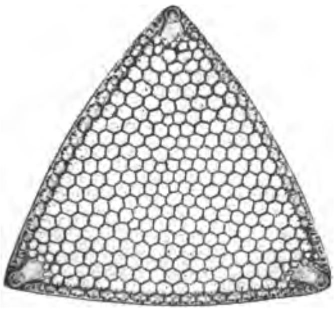
Considerable gravel, *whitish-gray* in color, was reported 1893 from the first well at the depth of 200 to 215 feet. In the second well (1894) a considerable quantity of gravel, also quite coarse, was obtained from the depth of 309 to 328 feet. The color of the second gravel is quite different from that of the first, and in comparison may be described as of a dull *grayish-yellow*.

The size of the gravel as obtained by the boring process employed was as large as peas, though possibly larger pebbles might have been contained in the bed, but these would not have been brought up without greater hydraulic pressure than was used. The average size of the pebbles in the first bed is about double that of those in the second. The latter were obtained by a different process.

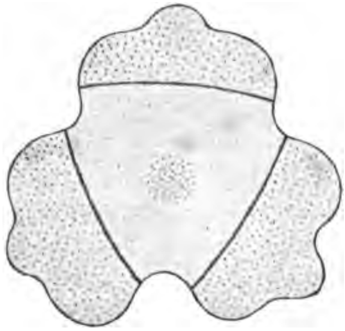
Considering the great similarity in the color and general appearance of the gravel at 309 to 328 feet, with gravels elsewhere that are believed to be Miocene, the writer would refer this bed thereto.

The upper bed, that at 200 to 215 feet, the writer considers bears an equally striking resemblance in color and appearance to gravels of later date, and that belong to some phase of the various Quaternary gravels in the State which are now being elaborately treated by Prof. R. D. Salisbury in these reports. Which phase, however, this deposit represents, we leave for future interpretation.

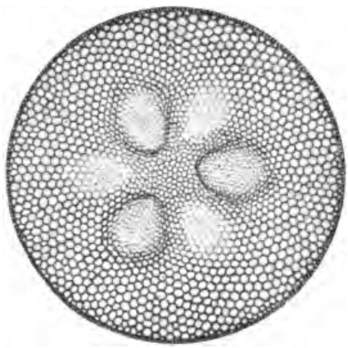
DIATOMS, ARTESIAN WELL, WILDWOOD, N. J.



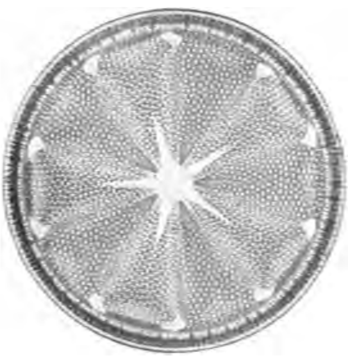
× 380.
TRICERATIUM FAVUS Ehrenberg.
Diatom Beds Nos. 1 and 2.



× 880.
HYDROSERA (TERPSINŒ) NOVÆ CÆSAREÆ Boyer.
New species. Diatom Bed No. 2.



× 220.
COSCINODISCUS EXCAVATUS Greville.
Diatom Bed No. 3.



× 200.
ACTINOPTYCHUS HELIOPELTA Grunow.
With five-pointed star.
Diatom Bed No. 4.

× 200.
ACTINOPTYCHUS HELIOPELTA Grunow.
With six-pointed star.
Diatom Bed No. 4.

MOLLUSCAN HORIZONS.

Below the base of the second gravel, that is, below the depth of 328 feet, and extending to that of 1,104 feet, are 775 feet of strata, mostly of solid clay, dark in color, with a bluish-green tinge when wet, as when brought out of the well, but which becomes gray when dried.* Small fragments of shells began to make their appearance in this bed at the depth of 370 feet, from which point downward the borings for this interval frequently showed, more or less sparsely, comminuted shell—a condition probably produced by the grinding of the drill. There were, however, three marked shell beds where molluscan fossils were especially numerous. These were at the depths of 409 to 428 feet, 705 to 732 feet and 887 feet. These three horizons will now be separately considered.

Molluscs 409 to 428 feet,—By a careful examination of the comminuted shell at 409 to 428 feet, undoubted fragments of a univalve shell, *Mèlanopsis Marylandica*, were identified. Associated with this form were a considerable number of other small shells, both univalves and bivalves, but these had been ground by the drill into such minute fragments that their identification as to species is impossible. The following genera may, however, be safely stated to be present: *Nassa* (plentiful), *Terebra*, *Turbonella*, *Assiminea* and *Yoldia*.

A comparison of this fauna with that listed on page 158, from the depth of 320 to 360 feet, nine miles southwest, at Cape May Point, would indicate that the same bed is represented in both wells, especially when we consider that the most numerous fossil at either locality is the *Melanopsis*, a shell that does not occur in either of the two lower horizons in this well, nor has the writer seen it in a very considerable collection of Miocene fossils that he has made from severel wells northward along the New Jersey coast.

As was stated in the notice of the Cape May Point well, this horizon is the same as that represented by outcrops at St. Mary's, Md., where also this *Melanopsis* is a distinguishing fossil and which locality is upon the upper part of the Chesapeake Miocene.

Molluscs at 705 to 732 feet and at 887 feet.—Judging from the specimens furnished, there are within the interval of 705 to 732 feet two shell beds between the respective depths of 705 to 713 feet and

* Included within these 775 feet of strata are the third and the fourth diatoms beds previously described.

at 718 to 732 feet. These may be practically viewed as a single horizon, the second from the surface. The third noticeable horizon is at the depth of 887 feet, and is reported to be about one foot thick. The shells were very numerous. From this depth to that of 960 feet a greater or less number of molluscs were brought to the surface. It is thought, however, that those from the lowest depths were really contributed from the bed at 887 feet, having dropped down as the boring proceeded and before being followed by the casing. A study of the specific forms, however, indicates that whatever may have been the actual depths from whence these specimens were brought up, but one faunal horizon is practically represented.

With the assistance of Prof. Heilprin and C. W. Johnson, the species occurring at 705 to 732 feet have been identified; while C. W. Johnson and the writer together carefully identified those from the depths of 887 feet (and lower ?).

The following tabular arrangement exhibits the fossils occurring at each horizon. It also shows at a glance those found only in the upper bed, those found jointly in both the upper and the lower of these beds, and likewise those found only in the lower bed. In nomenclature we have mainly followed Prof. R. P. Whitfield in his "Mollusca and Crustacea of the Miocene of New Jersey:"*

	705 to 732 feet.	787 feet.	Below (?) 787 feet.
FOSSILS OBTAINED FROM THE UPPER HORIZON = 705 TO 732 FEET.			
Axinea (*Pectunculus*) *Centiformis* Conrad	×	....	....
Dione Sayana Conrad	×	....	....
Pecten sp.?	×	....	....
Rangia (*Perrisodon*) *minor* Conrad	×	....	....
Actæon Sholohensis Whitfield	×	....	....
Amycla (*Columbella*) *communis* Conrad	×	....	....
Cadulus sp.?	×	....	....
Dentalium sp.?	×	....	....
Drillia subflexuosa Whitfield	×	....	....
Fasciolaria sp.?	×	....	....
Turritella secta Conrad	×	....	....
" *plebeia* Say	×	....	....
Trochita perarmata Conrad	×	....	....
Bryozoa	×	....	....

* United States Geological Survey, Monograph XXIV.

	705 to 732 feet.	787 feet.	Below (?) 787 feet.
FOSSILS COMMON TO BOTH HORIZONS = 705 TO 732 FEET AND 887 FEET (AND LOWER?).			
Astarte Thomasii Conrad	×	×	....
" *distans* Conrad	×	×	....
Arca (*Barbatia*) *Marylandica* Conrad	×	×	×
Corbula subcontracta Whitfield	×	×	....
Dasinea sp.?	×	×	....
Lucina Crenulata Conrad	×	×	....
Mactra (*schizodesma*) *delurnbis* Conrad	×	×	×
Pecten Madisonius Say	×	×	....
" *Humphreysii* Conrad	×	×	....
Venus latilirata Conrad	×	×	....
Busycon scalarispira Conrad	×	×	....
Drillia (*Pleuratoma*) *pseudeburnea* Heilprin	×	×	×
Naticu (*Lunatia*) *hemicrypta* Gabb	×	×	....
Turritella Cumberlandia Conrad	×	×	×
Nassa (*Tritia*) *Trivittitoides* Whitfield	×	×	×
Terebra curvilirata Conrad	×	×	×
Crustacean (Barnacles) = *Balanus proteus* Conrad	×	×	....
FOSSILS FROM LOWER HORIZON = 887 FEET (AND LOWER?).			
Astarte cuneiformis Conrad	....	×	×
Corbula inequale Say	....	×	×
" *elevata* Conrad	....	×	×
" *idonea* Conrad	....	×	×
Crassatella melina Conrad	....	×	....
Dosinea (*Artemis*) *Acetabulum* Conrad	....	×	....
Lucina trisulcata Conrad	....	×	....
Mactra (*Mulinia?*) *lateratis* Say	....	×	×
Neverita duplicata Say	....	×	....
Nucula proxima Say = *obliqua* (Say) Heilprin	....	×	×
Periploma alta Conrad	....	×	....
Solen sp.?	....	×	....
Nassa (*Tritia*) *bidentata* Emmons	....	×	....
Tellina producta Conrad	....	×	....
Turritella æquestriata Conrad	....	×	....
Venus Ducatelli Conrad	....	×	....
Venericardia (*Cardita*) *granulata* Say	....	×	×
Sea urchin = *Echinus*	....	×	×
Fish ear bones = *Otolithus* (*Scianidarum*) *elongatus* Koken	....	×	×

There are listed above 50 fossil life forms, 46 of which are molluscs. Of these molluscs, 13 were observed only in the upper horizon, and 17 only in the lower horizon, while 16 were found in both horizons.

Otoliths at 900 feet.—Associated with the molluscan fossils, at about this depth, were a considerable number of Otoliths, or the small ear bones of fishes. These Otoliths were all of them exactly alike, and therefore probably represented but one species. Ernest Koken, a German author, has written an admirable monograph upon Otoliths, and figures therein a form from Tertiary deposits of probably about the same age in northern Germany, which is identical with the one occurring here. He gives it the technical name of *Otolithus* (*Scianidarum*) *elongatus*.* These small ear bones are those of a fish belonging to the family of the *Scianidæ*, which includes the weakfish and the Cape May goody. We thus have had preserved, for our inspection to-day, portions of the remains of possibly the ancestors of the identical fishes now swimming in the waters of our coast.

Immediately below this shell bed occurs the water-bearing sand from which this well, after having been continued deeper, finally obtained its supply. This will be again referred to under the head of water horizons.

FORAMINIFERA.

At various depths within the 775 feet of Miocene strata now being described, Foraminifera were observed by the writer while making microscopic examinations of the borings. A careful listing of the various species found in this well was not made. It was very observable, however, that they were generally identical with forms studied by the author in the year 1889 from the same bed at Atlantic City, when the following genera were then noted,† viz., *Nodosaria*, *Dentalina*, *Cristellaria*, *Robulina*, *Nonionina*, *Rotalina*, *Rosalina*, *Bulemina*, *Uvigerina*, *Amphistigina*, *Guttulina*, *Biloculina*, *Triloculina* and *Textularia*. Many of the forms closely resemble species described in 1846 by d'Orbigny from the Miocene clays around Vienna, Austria.

* Zeitschrift der Deutschen Geologischen Gesellschaft, page 560, table XII., figure 6.

† Proceedings Acad. Nat. Sci., Philada., 1890, page 143.

COCCOLITHS AT 1,040 FEET.

In the clays at the depth of 1,040 feet were a number of minute microscopic calcareous objects which have been named coccoliths by Huxley. They are less in size than most of the smaller diatoms, and require a magnification of about 200 diameters to be seen at all satisfactorily. In shape when seen edgewise they much resemble a collar stud, and consist of a small, circular or oval disc joined by a shaft to a slightly larger disc, also circular or oval, as the case may be. In the last or seventh edition of "Carpenter's Microscope and its Revelations," by Dollenger, it is stated that they are "from $\frac{1}{8000}$ to $\frac{1}{1600}$ of an inch in diameter," and that they are "now very extensively diffused over the deep-sea bottom, being especially abundant in the globigerina mud."

According to Dana, coccoliths are also abundant in the Cretaceous of the eastern slope of the Rocky mountains. The writer has also observed them in Cretaceous outcrops in New Jersey.

CORAL.

Several fragmentary specimens of a cup coral (*Phacocyathus*) were obtained from the lower portion of the boring, but whether they came from the top or the base of the Eocene (?) greensand next described is not certain. This same coral was also found in the borings at Atlantic City.

GREENSAND MARL, EOCENE (?).

1,104 to 1,244 feet.

The interval from the depth of 1,104 feet to the bottom of the boring at 1,244 feet is occupied by what is practically one bed of a clayey glauconitic green sand. This deposit is stated by the well-driller to have been of a clayey nature because of the behavior of the drill while penetrating it. Its clayey nature may also be inferred from the fact that the walls of the well stood open without being cased. The hydraulic process used in drilling so washed away the finer clay particles that the specimens are mainly of clear sand, consisting of a mixture of white quartz grains and of glauconitic green-sand grains, the latter often showing beautifully the divisions of the foraminiferal chambers within which the glauconite was cast.

An open sand seam not more than ten feet thick occurs midway in this bed, namely, at the depth of 1,185 feet. This furnished a copious overflow of *salt* water.

On comparing this greensand bed with a very similar deposit occurring between the depths of 771 and 900 feet at Crisfield, Md., of which the writer has specimens, and also with a more arenaceous, though at the same time a largely glauconitic deposit encountered between the depths of 955 and 1,095 feet at Atlantic City, and considering the relative position of the greensand bed at the three localities, the writer is much inclined to the view that the same bed is represented at each place. N. H. Darton, in "The Transactions of the American Institute of Mining Engineers," February, 1894, describes the bed at Crisfield as a "dark olive-green argillaceous sand with a large proportion of glauconite," and refers it to the Pamunkey formation—the local name for a bed generally regarded as of Eocene age.

This view of the age of the bed is strengthened by a comparison of the clays below the green sands, both at Atlantic City and at Crisfield. Specimens of these clays from both places are in the writer's possession and are lithologically very similar. A pen-and-ink note written by N. H. Darton on the margin of the leaf of a copy of the above-named paper, which he sent to the writer, states that at 970 feet at Crisfield there were "clearly-defined Severn clays"—these belong to the Cretaceous.

The well-boring at Wildwood is said to have been discontinued upon the top of a clay bed. Of this no specimens were received. It was probably the same Severn or Cretaceous bed.

WATER HORIZONS.

In sinking the well small overflows of fresh water were observed at the depths of about 625 and 843 feet, while a much larger flow was obtained just below the shell bed that occurs at 887 feet. All these flows were from sands interbedded in Miocene clays. A strong flow of *salt* water, as already stated, was had midway of the Eocene (?) greensand at 1,185 feet.

The well was finally finished with a depth of only 931 feet and draws a good supply of fresh water by means of a fifty-foot strainer from the interval between 887 and 931 feet, which interval is occupied by a fine gray sand. This water horizon is probably the equiva-

lent of that at the depth of 750 to 800 feet at Atlantic City, Longport and Ocean City.* It may, however, be noted that this water-bearing stratum at the three last-named localities consists of a brownish, rather coarse sand, while at Wildwood the sand, as above noted, is gray in color and quite fine.

ROCK STRATA.

In the boring of wells in Miocene beds to the northward of Wildwood, solidified rock strata have either not been encountered at all, or, if found, but a single such stratum has been met with. On the contrary, such solidified deposits are quite frequent at Wildwood—ten such strata having been passed through, varying from eight inches to six feet in thickness. Their respective positions are shown in the accompanying vertical section. Plate V. These rock strata consist of a fine sandstone, at least only in part cemented by lime, since if pieces of the same be placed in acid they effervesce slightly, retain their shape, and do not disintegrate or become loose sand.

The Miocene sediments at Wildwood were generally much finer than at Ocean City, Longport and Atlantic City, but not so fine as at Crisfield.

The relations of the strata at Atlantic City and Wildwood are better demonstrated by the accompanying vertical sections (Plate VII.) of the wells at the two localities. These sections, as drawn, show practically a cross-section between the two places, although the rate of dip cannot be stated for the reason that we do not yet know the exact strike of the strata in Cape May county.

For correlation, we add on the right a columnar section of the wells at Crisfield, Md. On comparison of the latter with the Atlantic City to Wildwood section, it will be seen that the non-diatomaceous clays and the interbedded water-bearing sand which intervene in New Jersey between the base of the 300 to 400-foot diatom bed and the top of the Eocene (?) greensand marl are absent at Crisfield; also, that the great Miocene diatom clay bed thickens southward from Atlantic City.

* As this paper goes to press we learn that the same water-yielding sand has been again opened by a well recently finished at Brigantine, N. J. This sand is here again brown in color.

The reference now made of the beds at Atlantic City, below the depth of 955 feet, to the Eocene and the Cretaceous, is at variance with the identification made by the writer in the Annual Report for 1889, where the view was entertained that they are wholly Miocene. This view was then held because two or three Miocene shells were found in the specimens of these lower clays. It now seems to the writer quite possible that these were accidentally introduced from above.

If the lowest clays at Atlantic City—that is, those from the depth of 1,095 to 1,398 feet—belong to the Severn and Magothy divisions of the Cretaceous, it still remains an interesting question what are the relations of these to the Middle Marl bed—that is, are the true green-sand marls of the Middle Marl bed of New Jersey beneath these clays, or are the marls replaced by these clays?

ARTESIAN WELL, ATLANTIC CITY, BALTIC AVENUE, BETWEEN MASSACHUSETTS AND CONNECTICUT AVENUES.

Thoms B. Harper, of Jenkintown, has put down at the above location an artesian well for the Citizens Ice and Cold Storage Company. The well has a depth of 805 feet. An eight-inch casing was put in to the depth of 450 feet; below this a six-inch casing was continued to the depth of 790 feet. A four-and-a-half-inch strainer was then put in to the depth of 805 feet. The water, which is of excellent quality, flowed seven feet above the surface at the rate of 40 gallons a minute. The well has been pumped 125 gallons a minute, the full capacity of the pump, without apparently reducing the supply.

The water stratum developed is the same as has been opened by the Knickerbocker Ice Company's well, a few blocks southward, and which reached a total depth of 800 feet, and by the second well put down at Ocean City, ten or eleven miles southward, and which also has a depth of 800 feet. The same stratum is also probably opened at Wildwood, near Cape May, the depth there to the top of the water-bearing sand being 887 feet, and to the base, 931 feet. See report of this well, page 178.

The wells of the Consumers Water Company at this place, stated in past annual reports to have a depth of 760 feet, may possibly draw from this same horizon.

The water-bearing sand at this point and at Ocean City is brownish

in color* at the top, and changes to gray at the bottom. At Wildwood the entire thickness of the stratum is gray in color.

The following is the record of this well, as furnished by Thomas B. Harper, with some additional notes in brackets by the writer. As should be expected, it is substantially the same as has been published in previous annual reports respecting other wells at this locality:

Sand		surface to 20 feet.		Recent and Pleistocene, 275 feet.
Clay and marl	48 feet	= 20 feet to 68 "		
Sand and gravel	22 "	= 48 " to 90 "		
[Fine white clay at 88 feet.]				
[Fine white clay at 187 feet]				
Sand and clay	320 "	= 90 " to 410 "		
Black clay	150 "	= 410 " to 560 "		Miocene, 530 feet.
[Brackish water at 430 feet.]				
Coarse sand, brackish water	10 "	= 560 " to 570 "		
Clay with four sand seams	208 "	= 570 " to 778 "		
[Coarse sand at 763 feet]				
[Wood and shell at 765 ft.]				
Wood and clam shells	4 "	= 778 " to 782 "		
[*Venus mercenaria.*] Lennen.				
[*Artemis acetabulum.*] Conrad.				
Tough, dark clay, underlaid by coarse, brown sand, with some grains large as peas, water-bearing.	23 "	= 782 " to 805 "		

Thomas B. Harper also furnished specimens of clays from different depths. Those at 88 and 187 feet seem from color and character to belong to the Pleistocene. No fossils, microscopic or otherwise, were found in them. The clays from 400 to 700 feet are richly diatomaceous, in keeping with all other borings from the same interval at this place, and again prove the great thickness and persistence of the Miocene diatomaceous clay bed of the Atlantic coastal plain of the United States. The species of diatoms belonging to this bed are listed on pages 168 and 169.

ARTESIAN WELLS AT CRISFIELD, MD.

During the years 1892, '93 and '94, three artesian wells were sunk at Crisfield, Md. These will be designated as wells No. 1, No. 2 and No. 3. Well No. 1 has a depth of 1,006 feet. Well No. 2 reached

*Since the preparation of this paper a well has been put down at Longport to the same depth of 800 feet, and finding the same brownish sand, with an abundance of water, the flow from a six-inch pipe being 175 gallons a minute.

a depth of 1,060 feet, and draws its supply of water from below 1,040 feet. Well No. 3 has a depth of 980 feet, at which point further boring has been temporarily suspended. Wells Nos. 1 and 2 were put down for an ice manufacturing company by J. H. K. Shanahan, who has kindly furnished an excellent set of specimens of the borings, with full information respecting them. Well No. 3 was put down for the Crisfield Water Company, under the supervision of its projector and President, J. H. Buxton, who, appreciating the value of geological investigation, courteously and carefully preserved two full series of the borings, one of which he furnished to N. H. Darton and the other to the writer.

Wells Nos. 1 and 2 were drilled by the hydraulic or jetty process, which somewhat mixes the material and also washes away the finer particles, so that care has to be exercised in interpreting the meaning to be learned from the specimens. Well No. 3 was put down by the use of the ordinary drill and sand bucket, which method brings up the material in a condition nearly the same as that in which it occurs in the beds. For this reason the specimens obtained from this well are particularly valuable.

The deepest of the wells put down at Atlantic City—that reported in 1889, and which has a depth of 1,398 feet—was also put down with the drill and sand-bucket. As these two borings are the only ones of nearly so great a depth so far sunk by this process in the Miocene strata of our Atlantic coast, the specimens therefrom, both of which are in the State collections, are especially valuable for comparison and correlation, not only with each other, but also with borings already in hand from numerous other deep wells that have been put down by the other or the jetty method. They serve also as a check against drawing wrong conclusions from the latter.

N. H. Darton has already published in the "Transactions of the American Institute of Mining Engineers," at their February meeting, 1894, at Virginia Beach, a minute record of the strata passed through by well No. 3, with notes of fossils, and draws therefrom some geological conclusions. Previously, however, to the appearance of this paper, the writer had carefully examined the specimens received from wells Nos. 1 and 3, and compared the same with information obtained respecting all three of the wells, and had compiled the following record, which differs from N. H. Darton's in that the consecutive specimens, which are separately noted by him, when of a very similar character, are grouped in beds of considerable thickness,

thus making the record more simple and comprehensive. The references, however, of the lower portion of the section to the Eocene and the Cretaceous is upon the authority of N. H. Darton in the paper alluded to :

	Thickness.	Total depth.			
Sand and loam	15 feet.	15 feet.	= 52 feet Recent.		Recent, 52 ft.
Gravel	5 "	20 "			
Bluish clays and sandy clays, described as tough	32 "	52 "			
Gray sandy clays, with Miocene shells	58 "	110 "	= 313 feet of Miocene strata, containing molluscan and a few other fossils.	St. Mary's division.	Total thickness of Miocene, 719 feet.
Greenish clay	25 "	135 "			
Clay with flinty stones, 1 inch in diameter	5 "	140 "			
Clays and sandy clays, with scattering greenish grains,	100 "	240 "			
Miocene fossils at 135, at 190 to 215 and at 233 feet.					
Diatomaceous greenish clay,	10 "	250 "			
Greenish clay, with silicious limerock concerctions; lower 2 feet solid rock	20 "	270 "		Chesapeake division.	
Greenish clay, described as hard	75 "	345 "			
Miocene molluscs at 290 to 310 and 328 to 330 feet, the latter a decided shell bed 2 feet thick.					
Argillaceous sand	20 "	365 "			
Miocene molluscs at 345, at 352 to 370 and at 375 feet.			= 406 feet of Miocene strata, *diatomaceous* throughout, and representing the great 300-400-foot Diatom bed of the Atlantic coastal plain.		
Layers of sands and greenish clays, the latter slightly *diatomaceous*	25 "	390 "			
Alternations of sands, *diatomaceous* clays and *diatomaceous* sandy clays, mostly light greenish-gray in color	105 "	495 "			
Decidedly *diatomaceous* clays, light green and greenish-gray in color	115 "	610 "			
Sand and comminuted shell,	10 "	620 "			
Richly *diatomaceous* greenish clay	100 "	720 "			
Fine sand, slightly clayey	10 "	730 "			
Extremely rich *diatomaceous* clay, light colored and very light in weight	41 "	771 "			

	Thickness.	Total depth.		
Glauconitic indurated rock..	4 feet.	775 feet.		
Greensand marl................	75 "	850 "		
Gray clay, light greenish, considerable green sand, mixed, and a large number of *Foraminifera* and *Coccoliths*..	50 "	900 "	= 129 feet Pamunkey (?)	Eocene (?) 129 feet.
Dark greenish-gray clay......	30 "	930 "		
Greensand marl, with large foraminifera = *nodosaria*, &c............................	3 "	933 "		
Dark greenish-gray clay......	7 "	940 "	= 75 feet Severn (?)	
Light brownish clay...........	20 "	960 "		
Dark brownish clay............	8 "	968 "		Cretacious (?) 160 feet.
Black clay........................	2 "	970 "		
Light-colored clay..............	5 "	975 "		
Fine sand.........................	30 "	1,005 "		
Alternate layers of sand and stiff clay 1 to 4 feet thick, the clays predominating...	40 "	1,045 "	= 85 feet Magothy (?)	
Sand................................	15 "	1,060 "		

The first fifty-two feet of the above record are undoubtedly geologically recent, certainly not older than Pleistocene. It includes a five-foot bed of whitish quartzose gravel, many of the pebbles of which are the size of shellbarks.

The next 719 feet, or from the depth of 54 feet to that of 771 feet, belong to the Miocene, as is evidenced by the characteristic Molluscan fauna and by the occurrence in the lower half of a rich assemblage of marine diatoms, several of the species of which belong only to the great Atlantic coastal Miocene diatom bed.

This Miocene section of over 700 feet of strata is naturally divided at the depth of 365 feet into an upper division about 300 feet thick, containing throughout a considerable Molluscan fauna, and a lower division about 400 feet thick, containing an abundance of microscopic fossil diatoms, and but few molluscs.

The relative thicknesses of these various divisions may be seen by references to the section of this well on the right of Plate VII.

The two subdivisions of the Miocene will now be separately considered.

UPPER PORTION OF THE MIOCENE.

In the interval between the depths of 52 and 375 feet the following fossils occurred at the particular depths named. The list includes a few reported by Darton. These are marked N. H. D.

The identification of the fossils in the author's hands, both in this and in the lower section, was made by C. W. Johnson:

At 52 to 60 feet, *Nucula obliqua* Say. = *proxima* Say., *Mactra* (*fragosa?*) Conrad.
80 feet, fragment of large clam (not identifiable.)
13 to 100 feet, shell fragments. N. H. D.
100 to 110 " " " N. H. D.
110 feet greensand grains, scattering.
120 " " " still scattering but more plentiful.
130 " many shells. N. H. D.
135 " *Venericardia* (*Cardita*) *granulata* Say.; also *Perna* and *Arca* fragments.
140 " shells. N. H. D.
145 " greensand grains again.
177 " shell fragments. N. H. D.
185 " fragments of *Perna*. N. H. D.
190 " shells. N. H. D.
190 " *Pecten Madisonius* Say., *Ostrea* sp.? *Mactra lateralis* Say, *Turritella plebeia* Say.
215 " *Balanus proteus* Conrad.
233 " " " "
235 " shell fragments. N. H. D.
245 " marine diatoms.
240 to 268 feet, fragments of lignite. N. H. D.
285 feet, shells. N. H. D.
290 " *Turritella plebeia* Say., *Nassa* (*Tritia*) *peralta* Conrad. *Amycla* (*Columbella*) *Communis* Conrad. *Venericardia* (*Cardita*) *granulata* Say.
310 " Lignite and shell fragments N. H. D.
310 " *Dentalium attenuatum* Say. *Turritella plebeia* Say., *Polyneces* (*Natica*) *perspectiva* Rogers.
328 to 330 feet, a decided shell bed two feet thick containing *Turritella plebeia* Say. (numerous), *Scalaspira strumosum* Conrad, *Venericardia* (*Cardita*) *granulata* Say., *Venus alveata* and fragments of a large clam not identifiable.
345 feet, shell fragments. N. H. D.
345 " *Turritella plebeia* Say.
352 " *Isocardia Markoei* Conrad, *Pecten Madisonius* Say., *Balanus proteus* Conrad.
350 to 360 feet, fragments of *Pecten Madisonius* Say. N. H. D.
370 feet, *Pecten Jeffersonius* Say. N. H. D.
375 " *Pecten Madisonius* Say.

LOWER PORTION OF THE MIOCENE.

From the depth of 365 feet to that of 771 feet, few molluscan fossils were found, but almost every foot of this entire division contains numerous microscopic fossils known as diatoms, associated with which are also other miscroscopic fossils, viz., sponge spicules, foraminifera and polycistina. The following shows the results of the author's

examination of specimens from each of the various depths named. N. H. Darton's notes for the same interval are also introducd, marked N. H. D.:

At 365 feet, diatoms and sponge spicules.
375 " "
386 " "
390 " "
400 " "
410 " "
420 " "
From 420 to 465 feet, no specimens were secured.
At 460 feet, shell fragments. N. H. D.
465 " diatoms.
466 to 470 feet, shells.
469 feet, shell fragments. N. H. D.
475 " diatoms.
485 " "
490 " " and sponge spicules.
495 " " " " "
500 " " " " "
510 " *Turritella plebeia* Say.
515 " diatoms. (Diatomaceous. N. H. D.)
520 " *Turritella plebia* Say.
520 " diatoms plenty, some sponge spicules.
530 " "
535 " diatomaceous. N. H. D.
545 " diatoms plenty, *Drillia limatula* Conrad.
550 " " *Actinocyclus.*
555 " " (Diatomaceous. N. H. D.)
565 " " and sponge spicules. (*Turritella plebeia* Say. N. H. D.)
575 " " *Triceratium Marylandica*, also *Actinocyclus.*
600 " " and sponge spicules.
605 " " rich, also polycistina and foraminifera.
600 to 605 feet, diatomaceous, also *Macoma.* N. H. D.
610 feet, shell fragments. N. H. D.
620 " " " N. H. D.
620 " diatoms scanty, sand and shell.
640 to 650 feet, diatomaceous. N. H. D.
640 feet, diatoms and a few foraminifera.
650 " " rich.
660 " " and a few foraminifera
660 " diatomaceous, also *Macoma.* N. H. D.
670 " diatoms not plentiful, sandy.
675 " " and sponge spicules.
680 " " sponge spicules, polycistina and foraminifera.
675 to 690 feet, diatomaceous. N. H. D.
710 feet, diatoms very rich. (Diatomaceous. N. H. D.)
720 " " " " also large glauconite grains.
730 " "

740 feet,	diatoms	very rich.	(Diatomaceous,	dark buff. N. H. D.)
750 "	"	" "	("	light gray. N. H. D.)
760 "	"	" "	("	darker gray. N. H. D.)
765 "	"	medium.		
790 "	"	*Heliopelta.*		

It may be here stated that among the greensand borings at the depth of 790 feet, and therefore just below the point which lithologically marks the divisions between the Miocene and the Eocene, there was found a diatom, *Heliopelta,* always elsewhere characteristic of the base of the Chesapeake Miocene. It may be that there has been some mixture in this case, either of the borings, or possibly when the diatom bed began to be formed some of the Eocene green sands were worked over again and deposited simultaneously with the diatom clays. That there has been some mixture, however, is favored by the fact that the specimens examined were from well No. 1, which was put down by the jetty method.

From a preparation of diatoms from the upper portion of this bed the author made a strewn mount upon which C. Henry Kain, an authority, readily recognized the following forms, thirty-one in number. This is probably not more than one-sixth the number of species occurring in the beds. The list, however, is sufficient to demonstrate to diatomists that the forms here assembled must have come from the great Atlantic-coastal-fossil-diatomaceous deposit first discovered about 1840 by Rogers, at Richmond, Va., which city it underlies, and where it is well exposed along the high and steep banks of Shokoe creek, which cuts across that city on its way to the James river:

Coscinodiscus apiculatus Ehr.
Coscinodiscus robustus Grev.
Coscinodiscus marginatus Ehr.
Coscinodiscus radiatus Ehr.
Coscinodiscus excavatus Grun.
Coscinodiscus oculus iridis Ehr.
Coscinodiscus lineatus Ehr.
Coscinodiscus perforatus Ehr.
Coscinodiscus symmetricus Grev.
Actinocyclus Ehrenbergii Ralfs.
Actinocyclus Ralfsii W. Sm.
Actinoptyclus vulgaris Schuman.
Actinoptyclus undulatus Ehr.
Actinoptyclus areolatus Ehr.
Rhaphoneis amphiceros Ehr.
Stephanopyxis turris Grev.
Stephanopyxis limbata Ehr.
Hattonia Reichardtii Grun.
Eupodiscus Rogersii Bailey.
Melosira sulcata (Ehr.) Kütz.
Mancula didyma Ehr.
Pleurosigma Virginiacum Peticolas.
Systephania corona Ehr.
Systephania diadema Ehr.
Pyxilla Americana (Ehr.) Grun.
Dicladia capreolus Ehr.
Hyalodiscus subtilis.
Goniothecium odontella Ehr.
Goniothecium Rogersii Ehr.
Stephanogonia polygona Ehr.
Triceratium Marylandicum Bright.

Actinoptychus Heliopelta, previously mentioned as occuring in the borings from this well, does not appear in the above enumeration of forms, because its position is lower down in the bed than the point from which the material was taken which furnished the forms listed. This diatom may be considered to be just as distinctively characteristic of the base of the Chesapeake Miocene as the molluscan fossil *Melanopsis Marylandica* is of the St. Mary's or upper division thereof, or as *Turritella Mortoni*, another mollusc, is of the Eocene.

The next division occupies the interval between the depths of 771 and 900 feet, and is separated from the diatom bed above by about four feet of indurated rock, showing on fresh fracture one mass of beautifully bright-green grains of glauconite. This division is a twofold one, the upper two-thirds, or from 771 to 850 feet, being almost wholly of pure green sand, while the lower one-third, or from 850 to 900 feet, is very largely composed of a light-greenish clay of very fine texture containing many foraminifera and Coccoliths with a considerable sprinkling of green sand.

We refer this division to the Eocene on the authority of N. H. Darton, who says: "The coarse highly-glauconitic sands beginning at 780 feet are typical of the Pamunkey formation [= Eocene] and the siliceous stratum [771 to 775 feet] and scattering grains of glauconite characterize the base of the Chesapeake in surface outcrops west of Chesapeake bay."

A similar siliceous stratum has been observed by the writer between the base of the Miocene diatom bed and the top of the Eocene green sand along the bluffs of the Patuxent river near Nottingham.

The following are the author's notes of the microscopic examination of this section. There are also introduced N. H. Darton's notes:

771	feet to 775 feet, rock with large grains of glauconite.		N. H. D.
780	" glauconite olive green; also foraminifera.		
790	" " and diatoms, *Heliopelta*.		
800	" " dark green; also foraminifera.		
		800 feet, glauconite, fine grains.	N. H. D.
		810 " shell, oyster.	
		820 " glauconite, coarser grains.	
815	" glauconite, dark green, foraminifera.		
825	" " " " "		
842	" " grains, " also coccoliths.		
860	" " " and coccoliths.		
875	" " "		
890	" " " and coccoliths.		

The next general division, that from the depth of 900 feet to that of 975 feet, is made up of peculiar tough clays that cut like cheese when wet, and that vary in color, being dark green, light gray, light and dark brown, and even quite black. The microscopic examination presents for different depths the features noted below:

At 920 feet, coccoliths.
930 to 933 feet, glauconite, foraminifera (= *Nodosaria*) *Balanus* and shell fragments.

This is a stratum three feet thick, of nearly pure greensand grains, mingled with which were some fragments of shell, and also of barnacles, *Balanus proteus* Conrad. Especially notable, however, was the presence of a large foraminifera, a *Nodosaria* identical with a form occurring in strata immediately over the Middle Marl bed of New Jersey.

At 940 feet, coccoliths.
955 " no micro-organisms.
968 " " " "

From the lowest section, that from 975 to 1,060 feet, but few specimens of strata were received, and these were sands from the upper part, which, excepting small fragments of lignite at 980 and 1,005 feet, showed no fossils microscopic or otherwise. The description noted above, "alternate layers of sand and stiff clay, one to four feet thick, the clay preponderating," was taken from a letter from contractor J. H. K. Shanahan.

These two lowest divisions are respectively referred to the Severn and the Magothy divisions of the Cretaceous, also on the authority of N. H. Darton, who, in a copy of his paper read before the American Institute of Mining Engineers, which he furnished the writer, and which he revised with pen and ink, says (after revision): "It is possible that the water bearing sand [at 1,006 feet] is at the base of the Severn formation and is probably in the Magothy sands."

For a more graphic correlation of this well section with sections at Wildwood and Atlantic City, N. J., the reader is referred to the engraved sections, Plate VII.

ARTESIAN WELLS IN CRETACEOUS STRATA.

We now report wells in Cretaceous strata. Included with these is one well upon the Pennsylvania side of the Delaware river, but which draws from beds that belong to and are directly connected with the New Jersey series. These wells will be presented in the order of

their geographical position, commencing at the southwestern end of the Cretaceous belt, and continuing to the northwestern end, excepting, however, that a group of twenty-one wells in the region of Marlton and Medford will be reserved for special consideration, following the others. The wells to be reported are located at Bayside, Greenwich, Quinton, Harrisonville, Wenonah, Magnolia, Pavonia, Philadelphia, Riverside, Bordentown, Hightstown, South Amboy and the region around Marlton and Medford.

With these records there are inserted two vertical cross-sections, one illustrating the wells and the stratigraphical structure of the region about Marlton and Medford, and the other showing the same for a much wider belt—being a section from Mullica Hill to Millville.

Both these sections show the depth beneath the surface at various localities of the water-bearing sand immediately below the Middle Marl bed. Such depth is indicated at a number of places where there are, as yet, no artesians reaching the Cretaceous; among these are Bridgeton, Hammonton and Vineland.

ARTESIAN WELLS AT BAYSIDE AND GREENWICH.

Notice of an artesian well at Greenwich, with a depth of 690 feet, was made in the Annual Report for 1885, and of one at Bayside with a depth stated at 160 feet, was made in the report for 1889.

During the past year, upon the re-arrangement of the collections of the Survey in the State Museum, at Trenton, specimens from the well at Greenwich, from the depth of 360 feet downward, were discovered. An examination of these specimens, microscopically and otherwise, results in some addition to our knowledge. The former report was void of information respecting the strata above 360 feet; this is, in part, supplied by the record of the well at Bayside, one and one-half miles southwest, and nearly upon the line of strike of the strata. The Bayside well records the first 190 feet, leaving an interval of 170 feet between the depths of 190 and 360 feet of which we have no description.

The following combined record of facts respecting the two wells, describes the stratigraphical structure of the region so far as known. The record of the Bayside well is taken mainly from the report for 1889, but also includes some additional information that was recently furnished by Maskell Ewing, of Greenwich.

COMBINED SECTION.

WELL AT BAYSIDE.

33 feet.	Marsh mud		to 33 feet.	Recent.
2 "	Hard clay	33 feet	" 35 "	Miocene.
	Salt water		at 100 "	
	(Flowed 18 inches above the level of the marsh and probably 2 feet above high tide.)			
	Salt water again		" 140 "	
	(Very salt, cold and clear.)			
30 "	Hard clay	160 "	to 190 "	
	(This clay came up in little, blue chunks almost as hard as chalk.)			

WELL AT GREENWICH.

Interval, no record	190 "	" 360 "	Age not determined.	
Sandy clay	360 "	" 400 "	Middle marl.	Cretaceous.
Clay containing *Textularia** and other foraminifera	400 "	" 450 "		
Micaceous sandy clay	450 "	" 525 "		
Greensand, with shells = *Gryphea*, also *Textularia* and other foraminifera	525 "	" 550 "		
Green and white sand, greensand grains and Coccoliths †	550 "	" 580 "		
Green and white sand similar to that at	550 "	" 580 "		
Textularia and Coccoliths	580 "	" 600 "		
Greenish sand. Coccoliths, *Textularia* and greensand grains	600 "	" 625 "	Lower marl.	
Greensand, with *Gryphea* shell	625 "	" 642 "		
Greensand	642 "	" 650 "		
Black micaceous sandy clay	660 "	" 675 "		
Black micaceous sandy clay	675 "	" 690 "		
Sandy clay, somewhat lighter in color, contains Coccoliths		at 690 "		

* *Textularia* is one of the genera of the foraminifera, which are minute forms of animal life with calcareous coverings. The forms occurring here are invisible without the aid of a microscope.

† For a description of Coccoliths, see page 177. They are much more minute than the *Textularia*, above noted, and require about six times greater magnification to see them satisfactorily.

Directly in the village of Greenwich, at a slightly higher elevation than that where Job Bacon's well is located, there occur loose in the soil fragments of rock containing silicified casts of shells. Similar silicified rock with the same shell casts was encountered in digging a well close by with a depth not greater than ten feet. These shells are of Miocene age. A number personally collected by the writer were submitted to C. W. Johnson, of the Wagner Institute, who identified the following species:

Ostrea (*percrassa?*) Conrad.	*Nassa peralta* Conrad.
Venus mercenaria Linnæus.	*Pecten* sp.?
Mactra sp.?	*Turritella variabilis* Conrad.

We are also informed that this stone was at one time quarried in the vicinity at the edge of a meadow bordering a creek.

These facts considered in connection with the relative position of this locality with that of the Miocene shell marls to the northward, near Shiloh, and not more than six miles distant, indicate that the Greenwich well entered almost immediately beneath the surface into Miocene strata. The hard clays described in the Bayside well probably represent the great Miocene diatomaceous clay bed of the Atlantic coastal plain. The upper part of the undescribed interval, between 190 and 360 feet, is also probably Miocene, but the lower portion possibly represents the transition from Miocene through the Eocene into the Cretaceous.

The remaining portion of the Greenwich boring, viz., from 360 to 690 feet, is undoubtedly Cretaceous, as is evidenced by the fossil shells (*Gryphea*) and the succession of strata.

The absence of any record or any specimens of the lime sand that elsewhere overlies the Middle Marl bed leaves the occurrence or non-occurrence here of this marked stratum yet to be demonstrated.

The specimens in the State Museum corroborate the statement made by Prof. Cook in the report for 1885, that "the Middle Marl bed, with its characteristic fossils and greensand, was passed at 550 feet, and the Lower Marl bed, with its equally characteristic fossils and greensand, was passed at 650 feet." Below the latter depth the boring was continued into the clay marls.

Neither the well at Greenwich nor the one at Bayside was successful in obtaining water. It is, however, probable that a reliable well-driller, by the aid of the improved methods more recently in use, coupled with the knowledge gained by experience during the years

since these wells were put down, would now be able to develop one or more horizons within the limits of the depth reached by the well at Greenwich. Other water horizons also probably exist still lower, both within the clay marls and also at the base of the underlying plastic clays.

ARTESIAN WELLS AT QUINTON, N. J.

Elevation, 10 feet; diameter of each well, 6 inches; depth, 248 to 275 feet. Water rises nearly to the surface.

In last year's annual report, full details respecting a boring made at Quinton were published. During the present year, nine additional six-inch wells have been put down for the same water company, the contractors and the civil engineers being the same as those employed last year. Specimens were courteously furnished from several of these wells. They confirm in every respect the record of last year, including the thickness then reported for the first time of over 100 feet for the lime sand. As the record of the well of last year is almost if not identically the same as that for either of the wells of this year, that record is here reprinted entire.

The wells are each six inches in diameter, and are located upon ground varying somewhat in elevation. The depth of each is as follows:

Well No. 1, 248 feet; No. 2, 250 feet; No. 3, 255 feet; No. 4, 253 feet; No. 5, 266 feet; No. 6, 267 feet, and Nos. 7, 8, 9 and 10, each 275 feet. We are informed that the wells are pumped direct, and produce about 300,000 gallons of good clean water daily.

ARTESIAN WELL AT QUINTON, N. J.

(From last year's report.)

"A six-inch artesian well was bored in the fall of 1892 at Quinton, N. J. It was put down for the Salem Water Company, under the supervision of I. S. Cassin & Son, civil engineers. The drilling was done by Kisner & Bennett. Charles W. Casper, President of the company, and I. S. Cassin, Jr., cordially furnished notes of the strata passed through and also divided with the writer a series of specimens that had been preserved. Further samples were collected from lumps of clay that were still lying about and which had been thrown out from a dug well put down some years previously to the depth of about thirty-five feet.

"After a careful examination of all the specimens and comparison with the notes, the following record has been made:

1. Surface soil.............	1 foot.	1 foot.	Recent.	
2. Gravel....................	3 feet.	4 feet.		
3. Clay, with shells......	26 "	30 "	Astringent clay or rotten-stone.	Miocene.
4. Green and white sandy, clayey marl,	8 "	38 "	Upper marl (?)	Cretaceous.
5. Alternations of lime sand and lime rock,	108 "	146 "	Lime sand.	
6. Clay......................	2 "	148 "	Middle marl.	
7. Greensand marl and shell comminuted by the drill..........	14 "	162 "		
8. Clay......................	4 "	166 "		
9. Gray quartzose sand, with *water*...........	82 "	248 "	Red sand bed.	

" The elevation of this well is about ten feet above tide.

" That the clay (No. 3) is Miocene, is shown by the following fossil shells found in the lumps obtained from the dug well: *Lucina contracta, Yoldia limatula, Corbula elevata, Astarte undulata, Turritella plebeia* and numerous fragments of another shell believed to be *Artemis acetabulum.**

"Shells were also shown in the borings from the drilled well, but so thoroughly comminuted as to be entirely unidentifiable. Stratum No. 4, in the washed-out borings, appears as a sand, but in the lumps from the bottom of the dug well it is shown to be more compact than sand, and is better described as a sandy, clayey marl. It contains white sand grains and pure greensand grains, with a considerable mixture of foraminifera. This stratum probably represents the lower layer of the Upper Marl bed.

" The alternations of lime sand and lime rock (No. 5), are especially interesting, since they unexpectedly reveal a thickness of 108 feet for this upper member of the Middle Marl, as against twenty-five feet, the maximum thickness heretofore known from outcrops, and which, therefore, exhibit only the basal portion of this lime stratum. This section consists of an aggregation of Bryozoa, large and small foraminifera and coral.†

"Stratum No. 6 is the true marl of the Middle Marl bed, and shows clustered greensand grains beautifully illustrative of the casts of Globegerina, which they really are. This greensand comes out so pure that it is called, by well-drillers, " powder-grain marl." With it

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* Later examination has discovered also *Venericardia* (*Cardita*) *granulata*.

† This bed is judged, from the character of these fossil remains, to have been deposited close to the shore of the ancient Cretaceous sea, and at a depth of not, perhaps, over 100 feet. At all events, no trace of a deep-sea deposit is shown in the borings, as Dr. W. H. Dall writes, after examining some of the material which had been sent him.

is seen some finely-comminuted shell, probably from the Terrebratula layer that is so generally shown in outcrops of the same marl.

"The lowest ten feet of the lime sand and all the underlying strata, Nos. 6, 7, 8 and 9, correspond with beds penetrated by the wells at Woodstown, between the depths of 8 and 134 feet. No. 6, however, shows a difference in composition—here it is a thin clay seam, there it becomes a correspondingly thin cemented shell rock or coquina.

"The water, both at Woodstown and Quinton, is obtained from a pure, clean sand, No. 9 in above record, showing at both localities a thickness of eighty feet. This is the equivalent of the so-called red sand bed that occurs below the Middle Marl. At outcrops its color is frequently reddish, but in these wells it changes to gray.

"This water horizon has also been opened by a well one and three-quarter miles southeast of Mullica Hill, and is doubtless quite extensive. It is probably identical with the one at Asbury Park below the Middle Marl or at the depth of 425 feet from the surface. The bed, however, seems to thicken in this more southern region, where it furnishes a large supply of good water. The yield at Quinton is stated at about fifty-five gallons per minute, and at Woodstown at about sixty gallons. The wells at both localities have a diameter of six inches. The elevation of the surface at Quinton is about ten feet, and the water rises to within one foot thereof. This sand bed should be expected to yield a good supply at Glassboro and eastward and southward therefrom."

ARTESIAN WELL AT HARRISONVILLE.

Elevation, 120 feet; depth, 122 feet; diameter, 1½ inches.

During the summer of this year a well was put down by Charles H. Leach for Joseph Cheeseman, one mile east of Harrisonville, the elevation of the surface being 120 feet.

The father of Joseph Cheeseman had formerly a dug well on the same spot with a depth of eighteen feet which answered for water-supply until the surrounding woodland was cleared off, when it became necessary to deepen the well, which was done by digging to a depth of fifty-five feet from the surface. The most of the interval from eighteen to fifty-five feet was through what is described as a "bad-smelling blue clay." The present boring, which has a diameter of one and a half inches, was commenced at the bottom of the fifty-five-foot well. The record of strata compiled from the information furnished respecting both the dug and the drilled wells, and after comparison with specimens of the borings from the latter, is as follows:

Superficial gravel, with pebbles large as walnuts and larger, some streaks of yellow clay at the bottom	18 feet.		Pleistocene.
Bluish clay	37 "	55 feet.	Miocene (?).
"Bluish-green, muddy, marly clay"	25 "	80 "	Miocene (?).
White quartzose sand, with greensand grains	10* "	90 "	Cretaceous.
Alternations of lime sand and lime rock, composed largely of Bryozoan and foraminifera	28 "	118 "	Cretaceous.
Quartzose sand, *water*	4 "	122 "	Cretaceous.

There is said to be plenty of water in the four-foot stratum of sand at the base. The supply evidently comes from a sand interbedded within, but probably near the base of the lime sand that overlies the Middle Marl bed. This lime sand but a few miles to the eastward has probably a thickness of 100 feet, corresponding with that revealed at Quinton. See page 194.

ARTESIAN WELLS AT WENONAH.

Elevation, 10 feet; depth, 196 feet.

During the year, two wells, each three inches in diameter, were bored by Kisner & Bennett to supply the water works at Wenonah. Each well has a depth of 196 feet. They are both located upon the flood plain of a small tributary of Mantua creek, at an elevation of about ten feet above sea-level.

These wells are about one-half mile northwest of the well reported last year as having been put down by Orcutt Bros., at the Wenonah Hotel, to a depth of 345 feet, the elevation of the surface being about seventy feet.

The wells now under notice missed, in consequence of their lower position, the fifty-two feet of superficial loams and gravels of Quaternary age passed through by the previous well. This gravel has been eroded by the stream from the locality of this well, but is beautifully shown higher up in the railroad cut made through the hill which forms the west bank of the small valley occupied by the stream.

The record of each well is as follows:

Marsh mud	8 feet =	0 feet to	8 feet.	Recent.
Green sand	2 " =	8 " "	10 "	Clay marls—Cretaceous.
Bluish clay	164 " =	10 " "	174 "	Clay marls—Cretaceous.
Sand with water	22 " =	174 " "	196 "	Clay marls—Cretaceous.

*The thickness of this stratum is estimated; it may possibly be thinner. Its occurrence is known from a specimen taken at the depth of eighty feet, said to be next below the "bluish-green marly clay."

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The water rises to within six feet of the surface. This water horizon is higher stratigraphically than that opened by the well of last year. It is a bluish-gray, coarse sand within the clay marls and is doubtless the equivalent of the thirty-five feet of strata described in the well of last year as "gravel in streaks" between the depths of 245 and 280 feet. The lower water horizon described last year as "coarse sand and gravel," between the depths of 318 and 341 feet, is probably at or near the base of the clay marls.

The relations of these wells and of the one bored last year to each other and to the well at Sewell, reported in the year 1891, are shown in the annexed section.

ARTESIAN WELL AT MAGNOLIA.

Elevation, 94 feet; depth, 91 feet. Water rises to within 36 feet of the surface.

An artesian well was put down [near Magnolia station, on the Reading Railroad Company's route to Atlantic City, at a distance of eight miles, in a direct line, from the ferries at the foot of Federal and Market streets, Camden.

The following record, copied verbatim, was furnished by W. R. Kelly:

Yellow clay and sand	4 feet	=	0 feet to	4 feet.
Blue marl	32 "	=	4 " "	36 "
Coarse white sand, with water in it	5 "	=	36 " "	41 "
Coarse white gravel, with water in it	15 "	=	41 " "	56 "
Hard [stratum] like lime, with shells; these shells had ridges on them; the edges were scalloped	3 "	=	56 " "	59 "
Black sand, with marl grains	15 "	=	59 " "	74 "
Gray sand and shells cemented together, with a substance like lime; the strata would change about a foot apart	10 "	=	74 " "	84 "
Very dark, gray sand, with plenty of water	7 "	=	84 " "	91 "

W. R. Kelly remarks that the shells found in this well are different from those near the bottom of the well at Laurel Springs, and which belong to the Middle Marl bed. These probably represent the Lower Marl.

ARTESIAN WELL AT PAVONIA.

A six-inch artesian well was bored by W. C. Barr, at the Camden Pumping Station on the Delaware river. This well is located on the meadows at the corner of Delaware avenue and Union street, and near the foot of Fulton street.

W. C. Barr furnished specimens of the borings and also the following record, which we supplement with our own notes upon the right:

Black river mud	39 feet.	39 feet.	Recent—contains diatoms.	
Yellow and red mottled plastic clay	10 "	49 "	Plastic clays.	Cretaceous.
Red clay	23 "	72 "		
White sand	6 "	78 "		
Large, coarse gravel	5 "	83 "	Potomac gravels.	
White sand	2 "	85 "		
(Water in this rises to within 1½ inches of the surface.)				
Gravel and sand	4 "	89 "		
White clay	1 "	90 "		
Large gravel	8 "	98 "		
(Water in this gravel, which only rose to within 34 feet of the surface.)				
Gravel, clay and sand	16 "	104 "		
Soft [disintegrated] rock	8 "	112 "		

Then hard rock was encountered and the boring was discontinued.

ARTESIAN WELL CORNER OF LAUREL AND BEACH STREETS, PHILADELPHIA.

Sunk through the base of the Cretaceous series of New Jersey.

W. C. Barr furnishes the following interesting record of a well bored at the corner of Laurel and Beach streets, near Shackamaxon street ferry, Philadelphia, and about one and three-quarter miles slightly north of west from the well just reported at Pavonia:

Coarse gravel and sand to	58 feet.		Pleistocene.
Red clay	16 "	74 feet.	Potomac gravels—Cretaceous.
Gravel	4 "	78 "	
Rock clay	2 "	80 "	
Drilled into solid rock	228 "	308 "	and obtained a supply of good water.

After a personal interview with W. C. Barr, when he explained more fully the nature and color of the sixteen feet of red clay noted above, the writer is satisfied that the red clay and underlying gravel belong to the basal strata of the New Jersey Cretaceous plastic clays and their underlying Potomac gravels.

ARTESIAN WELLS AT RIVERSIDE.

One test-boring into crystalline rock, depth, 92 feet; and eight other wells, depth 36 to 40 feet; diameter of each, 6 inches.

During the summer a test-boring was made by Kisner & Bennett for the Riverside Water Company. By the co-operation of the officers of the company and the contractors, specimens of the borings were obtained, accompanied by notes respecting the strata.

The following is the record, with some notes added by the writer:

Yellow clay and pebbles surface to		8 feet.
Sand and gravel, orange color	5 feet =	8 feet to 13 "
Gray quicksand, contains fossil *Pinnularia* and other *fresh-water diatoms*	23 " =	13 " " 36 "
Gray quicksand, with water	6 " =	36 " " 42 "
White sand and white clay mixed	6 " =	42 " " 48 "
Sand and black mica (when wet the latter resembled graphite)	10 " =	48 " " 58 "
Disintegrated rock, very micaceous, black mica.	17 " =	58 " " 75 "
Hard, micaceous rock	17 " =	75 " " 92 "

Further work on this well was abandoned. Subsequently the same contractors put down eight other wells, each six inches in diameter, to an average depth of thirty-six to forty feet, developing the water-bearing sand indicated above, between the depths of thirty-six and forty-two feet. From these collectively, we are informed, there is obtained 250 gallons of water per minute.

It is interesting to note how near the surface the crystalline rocks are found at this point. Slightly south of west across the river and almost directly in the line of strike of the crystalline rocks in Pennsylvania, the same rocks rise to the surface and are extensively quarried at the Philadelphia House of Correction, near the mouth of the Pennypack. The white sand and white clay noted above at forty-two to forty-eight feet are indicative of a thin stratum of the plastic clays of the Cretaceous. In one of the other wells a thin stratum of red clay, alike characteristic of the plastic clays, was also found.

These wells are situated at the edge of the upland facing the Rancocas creek, near its mouth. The strata above forty feet are comparatively recent geologically. The gravels near the surface have been probably worked over from higher ground and redeposited upon the quicksands which overlie the water-bearing stratum.

ARTESIAN WELL AT BORDENTOWN.

Leach Bros., of Glassboro, report the following record of a well put down by them at a boat-house at Bordentown:

Surface			4 feet.		
Sand, water at 18 feet	4 feet to		18 "		
White clay	18 "	"	25 "		
Fine sand	25 "	"	57 "		Clay marls—Cretaceous.
Blue sand, with lignite; *water irony*	57 "	"	64 "		Clay marls—Cretaceous.
Alternations of thin seams of clays and sands	64 "	"	84 "		Clay marls—Cretaceous.
White sand, *water irony*	84 "	"	90 "		Clay marls—Cretaceous.
Alternations of sands and clays	90 "	"	102 "		Clay marls—Cretaceous.
White sand, *water irony*	102 "	"	107 "		Clay marls—Cretaceous.
Compact clay	107 "	"	121 "		

At this depth the boring was stopped. This well probably entered the top of the plastic clays, at whose base good water may be expected. The water-yielding sands penetrated are impregnated with iron by the clay marls which immediately overlie them, and which do not furnish a good quality of water.

ARTESIAN WELLS AT HIGHTSTOWN.

Well	No. 1.	Elevation 108	feet, depth	76	feet.	
"	No. 2.	" 108	" "	500	"	(Entered crystalline rock at 482 feet.)
"	No. 3.	" 86	" "	428	"	

At Hightstown there have been drilled three wells for the Peddie Institute, the elevation of the surface and the depth of each well being as stated above. Well No. 1 was put down some years since, and is located at the building of the Institute. Of this well we have not been able to obtain a record. Well No. 2 is likewise located at the Institute building. It was drilled by Uriah White the present year (1894), and was prospected to the crystalline rocks, which were found at the depth of about 482 feet. At 500 feet the boring was discontinued. Well No. 3 was subsequently bored by the same contractor and finished at the depth of 428 feet, finding a supply of water in some coarse gravels and sands that occur near the base of the plastic clays.

From the evidence afforded by a series of specimens of clays, sands and gravels, taken at various depths from Well No. 2 and kindly furnished by the contractor, it may be stated that after passing the superficial sands this well penetrated the base of the clay marls, and at a depth, as near as may be judged, of about 200 feet, passed into the plastic clay series, in which it continued until the crystalline rock was reached at 482 feet, as already stated. Some coarse sand and gravel were found below the base of the clay marl and a short distance beneath the top of the plastic clays, and between the depths of 240 and 255 feet.

Still coarser gravels and sands were found at or near the base of the plastic clays at depths ranging from 385 to 435 feet. It is from this stratum that Well No. 3 draws its supply.

Some lignite occurred at the depth of 175 feet. The crystalline rock showed much white quartz, some mica and a few small garnets. A thin film at the surface of the rock at the depth of 482 feet was of an iron-rusty color.

ARTESIAN WELL AT SOUTH AMBOY.

Elevation, 25 feet.

W. C. Barr, of Camden, forwarded the following record of a well put down by him at South Amboy for the Pennsylvania railroad. He also furnished specimens of the borings:

Top sand, dark, surface to		2 feet.	
Yellow gravel	5 feet =	2 feet to 7 "	
Red sand	9 " =	7 " " 16 "	
Blue clay	6 " =	16 " " 22 "	Plastic clays—Cretaceous.
Red, firm sand	27 " =	22 " " 49 "	
Black clay	56 " =	49 " " 105 "	

An examination of the specimens shows that all below sixteen feet and possibly all below seven feet belong to the plastic clay series at the base of the Cretaceous.

SECTION FROM NEAR MULLICA HILL TO WINSLOW, BRIDGETON, HAMMONTON, VINELAND AND MILLVILLE, ILLUSTRATING THE DEPTH TO THE WATER-BEARING SAND BENEATH THE MIDDLE MARL BED.

Upon projecting and plotting to a vertical scale along a common northwest and southeast section line and at their proper relative distances apart, the borings at Woodstown and near Harrisonville upon the northwest, and at Glassboro and Quinton upon the southeast, we have presented a complete vertical section, two miles in horizontal extent, showing consecutively the beds from the Pleistocene gravels at the surface through the Miocene clays and the various lime, marl, sand and clay marl strata of the Cretaceous to the top of the plastic clays that form the basal division of the group of beds belonging to the last-named age in New Jersey. Such a section shows a dip of thirty-seven feet per mile southeast for the shell and belemnite crust or rock layer that separates the base of the Middle Greensand Marl from the top of the quartzose water-bearing sand beneath.

Upon extending the section to the northwest, so as to include the wells at Marlton and Medford, and continuing upward in that direction the line marking the shell and belemnite crust, it is found to coincide at the proper depth with the shell crust above the water-bearing sand in the last-named region. Continuing again the section in the opposite direction, to the southeast, and plotting thereon the boring at Greenwich, and extending at the same rate of dip the line marking the shell crust, said shell crust likewise coincides at the proper depth with the shell stratum reported by Prof. G. H. Cook as associated with the Middle Marl in the well at the last-named place. Such a section as that just described has been constructed and is here inserted. It shows for a distance of thirteen miles a regular and persistent dip of about thirty-seven feet per mile.

The section commences at the locality of Thomas Borton's well, near Mullica Hill, and continues southeastwardly across the strike of the strata, and indeed includes a somewhat wider belt than that above defined, being extended on the southeast so as to take in the localities of Winslow, Bridgeton, Hammonton, Vineland and Millville, at each of which places, as marked on the section, a dotted vertical line is projected downward to meet the line of the before-mentioned belemnite and shell layer, and show at each of these localities the

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probable depth to the top of the sixty-foot water-yielding sand next below the Middle Marl.

The earliest deep artesian well in the State is at Winslow, but it stops in a higher sand, and therefore does not reach this stratum, while the deepest of the two unsuccessful borings made a few years since at Greenwich and noticed in this paper, passed through this horizon, and probably failed to develop it from causes not then to be overcome, but which may now be controlled.

Artesian Wells in the Vicinity of Marlton and Medford.

In the vicinity of Marlton there have been bored, during the last two decades, a considerable number of artesian wells, most of which are within three miles to the eastward, though a few are within the same distance to the south and southeast.

There are also a few bored wells at Medford and within a distance of two miles north and northeast thereof. These latter wells are so situated as to be directly in the line of strike of the strata with those near Marlton. But few of these wells have been heretofore reported in the publications of the Survey. All that have come to the knowledge of the writer in this region are described in the following pages, including those to which reference has been made in past annual reports. In these cases the place of such reference is noted.

Wells in this region, after passing through a greater or less thickness of superficial sands and gravels of Pleistocene age, and in some instances also of some underlying deposits belonging to a somewhat earlier period, penetrate entirely through the Middle Marl bed and a crust of fossil shells at its base two to six feet thick, beneath which is found a gray sand with a plentiful supply of excellent water. The shell crust contains the valves of an extinct oyster (*Exogyra costata* Say.) which has a twisted or curved beak, and also certain cigar-shaped fossils called belemnites (technically, *Belemnitella mucronata* Schlot.) These two fossils are characteristic of the Lower Marl and its overlying sand, the so-called red sand bed, described in the Geology of New Jersey, 1868. The crust is evidently on top of the water-bearing sand and forms an impervious layer that prevents the percolation into this sand of the unsatisfactory water held in the overlying Middle Marl bed. The quality of the water is said to vary in the different wells, but the writer believes that if the casings

are properly put in, so as to completely shut off contamination with water from the sands and marls above the shell crust, that the supply will be found uniformily good and desirable.

A cross-section of this region, drawn to scale, is *here* introduced. See Plate X. It shows the relative position of these wells to each other across the strike of the strata, the section line being drawn from northwest to southeast through Marlton. It also shows the elevation above sea-level of the surface at each well, and likewise the depth of each and the beds passed through. Three wells to the southwest of Marlton, viz., at Woodstown, Gibbsboro and Harrisonville, are also projected in their proper position among these wells. The section shows very graphically that, except in four instances, all the wells draw from the same water horizon, and that the dip of the crust is about thirty-seven feet per mile to the southeast.

The four wells excepted are those of Mrs. John Wilkins and Isaac W. Stokes, which extend deeper, and those at Gibbsboro and Harrisonville, which stop higher up.

Mrs. John Wilkins' well draws from a sand some 200 feet deeper, near the base of the clay marls.

I. W. Stokes' well is supplied from a sand about 100 feet deeper than the shell crust, but which horizon the writer would consider as practically the lowest stratum of the same water-bearing (red?) sand bed.

The wells at Gibbsboro and Harrisonville are furnished from loose strata within the alternations of lime sand and lime rock next above the Middle Marl. It is doubtful if this lime sand will furnish everywhere a satisfactory quality of water. Such wells should probably be continued some sixty or seventy-five feet deeper to the sand beneath the shell crust. The close approach to this sand can be surmised, when sinking wells, by the appearance of the before-mentioned belemnites in the borings.

At Joseph Evans' a first and unsuccessful boring was projected a considerable distance into the clay marls.

Specimens from Joshua S. Wills' well, and from the wells at Woodstown and Quinton, show the occurrence of the lime sand that overlies the Middle Marl bed. This lime sand can be recognized by peculiar perforated, elongated, flat, calcareous bodies called *Bryozoa*. At Quinton this sand is over 100 feet thick, while in this region the greatest reported thickness is about twenty-five feet.

The wells of this region will now be reported in detail. They are situated at twenty-one localities, and are all bored wells except those at Locust Grove, which are dug wells. The wells are reported in the order of their occurrence upon the dip of the beds, those first noticed being farthest back upon the dip.

DUG WELLS TWO MILES WEST OF MARLTON, ON THE FARM OF ELLWOOD EVANS, AT LOCUST GROVE.

Elevation, 90 feet; depth, 32 feet.

Ellwood Evans states that upon his farm, near Locust Grove station, there are five wells with depths varying a foot or two, more or less, from thirty feet, according to the elevation of the surface.

One of these wells is very nearly upon the ninety-foot contour line, and has a depth of thirty-two feet. At thirty feet a stony crust, about six inches thick and containing belemnites, was encountered. There was no water just above this crust, but in a reddish sand immediately below, there is an abundant supply and of excellent quality.

This belemnite crust represents the same stratum that is noted in the pages immediately following as having been passed through near the base of all the wells in the region under consideration, of which we have full and authentic records.

The relation of this crust to the base of the wells is graphically shown in the accompanying vertical cross-section. The water-supply comes from the so-called red sand bed, as described by Prof. Geo. H. Cook in the Geology of New Jersey, 1868.

ARTESIAN WELL AT MARLTON N. J, AT THE RESIDENCE OF C. B. CHEW.

Elevation, 110 feet; diameter, 5⅝ inches; depth, 86 feet. Water rises within 24 feet of the surface.

The following is copied from the Annual Report for 1885, page 131:

"At Marlton, in Burlington county, an artesian well has been bored for Charles B. Chew, Esq., by Mr. Goldsmith Wilmot, of Haddonfield. The well is eighty-six feet deep and with a bore of five and five-eighths inches, and has been sunk through the Middle

Marl bed and down into a sandy layer in which the well ends. Unfortunately the notes in relation to the successive layers of material passed through are lost. In general, however, they may be described as follows:

Loam and gravel to the marl	20 feet	= 20 feet.
Black marl	6 "	= 26 "
Greensand marl	15–20 "	= 46 "
Chocolate marl	6 "	= 52 "
Thin stony crust		
Chocolate marl	6–7 "	= 59 "
Hard, black sand, which gradually grew lighter, until it became white. About 2 or 3 feet from the bottom struck a very hard boulder, and drove the casing through it.		
Total depth		86 "

"The water rose within twenty-four feet of the surface. The well was then tested with a pump driven by a steam engine, and the water was not lowered an inch after running the pump steadily for eight hours. The quality of the water is good; its temperature is fifty-three and one-half* degrees."

The so-called "hard boulder" near the base is undoubtedly the same shell crust containing belemnites that is noted in most of the following records of wells in this region.

ARTESIAN WELL IN MARLTON, AT THE RESIDENCE OF SAMUEL LIPPINCOTT.

Elevation, 110 feet; diameter, 5 inches; depth, 105 feet. Water rises within 18 feet of the surface.

The following record is furnished by W. C. Barr:

Top soil	15 feet	= 15 feet.		
Yellow sand	6 "	= 21 "		
Black mud	2 "	= 23 "		
Gray marl	3 "	= 26 "	= Lime sand.	Cretaceous.
Green marl	22 "	= 48 "	= Middle Marl.	Cretaceous.
Chocolate marl	32 "	= 80 "	= Middle Marl.	Cretaceous.
Gray sand and water	25 "	= 105 "	= Red sand.	Cretaceous.

The writer has been shown an internal cast of a small oyster, probably *Gryphea Bryani* Gabb., that was obtained from this well and a number of nodular specimens of the mineral vivianite. These have a bluish cast, and on a freshly-fractured surface present a metallic

*The temperature is now 58 degrees.

appearance. Chemically they are a phosphate of iron. Both the oyster and the vivianite undoubtedly came from the Middle Marl bed.

ARTESIAN WELL IN MARLTON, AT THE RESIDENCE OF HENRY BRICK.

Elevation, 110 feet; depth, 86 feet;

This well was bored by Stothoff Bros. It is located upon the main avenue in Marlton, and near the eastern end of the village, and about two blocks from the well of C. B. Chew. The ground has the same elevation, 110 feet, and the well the same depth, eighty-six feet, as C. B. Chew's well.

No details of strata for this well have been received. There are, however, still preserved specimens of two species of oysters, *Exogyra costata* Say, and *Gryphea vesicularis* Lamarck, that, judging from their iron-rusty color, probably came from the shell crust that is noted as occurring above the water-bearing sand in most of the records of the wells in this region. There is also a specimen of another oyster, *Gryphea vomer* Morton, that may possibly have come from a somewhat higher level. It is not so rusty in appearance and the shell has some of the greensand matrix attached. Specimens of vivianite, a mineral quite common in the Middle Marl bed, have also been shown to the writer.

ARTESIAN WELL THREE MILES SOUTHWEST OF MARLTON, ON THE PROPERTY OF MRS. JOHN WILKINS.

Elevation, 130 feet; diameter, 5 inches; depth, 316 feet. Water rises within about 22 feet of the surface.

This well was noted in the Annual Report for 1885, page 133, and erroneously stated to be "southeast of," instead of southwest of Marlton, from which it is distant about three miles. It is upon the property of Mrs. John Wilkins, and is very nearly on the line of strike of the strata with the wells of C. B. Chew, Samuel Lippincott and Henry Brick, in Marlton.

W. C. Barr furnishes from memory the following general description of strata:

Top soil and quicksand, including 2 feet of iron crust	30 feet	= 30 feet.
Marl, including 4 feet of coarse sand, with *water* not good	78 "	= 108 "
Green quicksand	120 "	= 228 "
Blue clay	98 "	= 316 "

Coarse yellow sand and gravel, with plenty of good water.

ARTESIAN WELL NEAR MARLTON, N. J., ON THE FARM OF AMOS B. WILLS.

Elevation, 100 feet; diameter 6 inches; depth of well 84 feet. Water rises within 22 feet of the surface.

In the spring of 1890, Stothoff Bros. put down an artesian well on the property of Amos. B. Wills, five-eighths of a mile south of Marlton. A supply of water was obtained at the depth of eighty-four feet. No specimens were preserved, and no record kept of this well. It, however, probably draws its supply, in part at least, from above the shell crust that covers the top of the red sand bed, since the water is quite irony. The well next described, which is scarcely one-quarter of a mile distant, furnishes good water, probably because communication with the water above this shell crust is completely shut off.

ARTESIAN WELL ON THE FARM OF SAMUEL J. EVES, NEAR MARLTON, N. J.

Elevation, 120 feet; diameter, 6 inches; depth, 114 feet. Water rises within 40 feet of the surface.

About the year 1891 or 1892, an artesian well was drilled by Stotthoff Bros. on the farm of Samuel J. Eves, three-quarters of a mile south of Marlton.

Mr. Eves recently furnished from memory the following description of the succession of strata, but without notes as to the respective thickness of each stratum:

No. 1. Between a light and a heavy loam.
2. Gravelly soil.
3. Quicksand.
4. Dark material, somewhat like marl.
5. Broken shells, like oysters.
6. Salt-and-pepper sand, with good water and plenty of it.
Total depth, 114 feet.

Specimens of the salt-and-pepper sand at the base show white quartz grains, glauconite or greensand grains, fragments of belemnites and a few foraminifera of Rotaline forms such as have been found in the Cretaceous elsewhere. The water is of excellent quality and undoubtedly comes from the red (?) sand bed beneath the shell crust that separates that bed from the overlying Middle Marl bed.

ARTESIAN WELL EAST OF MARLTON, UPON THE FARM OF J. W. BARR.

Elevation, 70 feet; diameter, 3 inches; depth, 68 feet.

W. C. Barr writes that he has sunk the past year a three-inch well for his brother, J. W. Barr, on the road from Green Tree (Evesboro) to Medford, and about two and one-half miles southeast of the first-named locality, and about two miles east of Marlton. He sends the following record:

Soil and green clay	10 feet	= 10 feet.	
Coarse sand and gravel	10 "	= 20 "	
Black and green marl	14 "	= 34 "	Middle marl.
Chocolate marl	30 "	= 64 "	
Shell crust, with *belemnites*	4 "	= 68 "	
Sand, water-bearing			Red sand bed.

Specimens of this last stratum were also thoughtfully furnished. It is made up of greensand grains (globigerina casts) and white quartz grains with a large mixture of broken fragments of shells.

Among these are fragments of some ponderous oyster, doubtless from their stratigraphical position, either an *Exogyra* or *Gryphea;* or possibly both. There are also fragments of a *Pecten* and unmistakable fragments of belemnites,* a cigar-shaped fossil.

These fossils show that the water horizon is at the top of the so-called red sand bed and beneath the Middle Marl bed.

* *Belemnitella mucronata* Schlot.

ARTESIAN WELL THREE MILES EAST-NORTHEAST OF MARLTON, ON THE FARM OF JOSIAH BALLENGER.

Elevation, 70 feet; diameter, 6 inches; depth, 76 feet. Water rises to within about 10 feet of the surface.

This well was put down in the fall of 1889, by Stotthoff Bros., from whom we learn that after passing about forty feet of marl in different layers they "found at the depth of seventy feet shells and little stems," the latter undoubtedly belemnites. The well was drilled to the depth of seventy-six feet, stopping in a clean, whitish sand. The water rose in the well to within about ten feet of the surface. It is of good quality.

ARTESIAN WELL BORED FOR ISAAC W. STOKES, AT MEDFORD.

Elevation, 75 feet; depth, 183 feet. Water rises within 17 feet of the surface.

This well was noted in the Annual Report for the year 1892, but as it presents upon the accompanying vertical section the feature of an additional water horizon stratigraphically lower than that shown by any other well in the vicinity, it is again brought to notice.

The following is taken from said report, page 302:

"This well was bored in 1889 (see report for that year, page 89) to a depth of seventy feet, but was continued the past year to 183 feet. The record is made up from the former annual report to seventy feet and below that from notes and specimens of the earths furnished by I. W. Stokes. The continuation of the boring was done by Stothoff Bros.

	Sand and earth	15 feet.	
(1)	Marl	30 "	45 feet.
	Sand, varying	15 "	60 "
	Shelly layers	4 "	64 "
	Coarse gray sand (*water irony*)	6 "	70 "
	(Depth of first well.)		
(2)	Green marl	15 "	85 "
	Black quicksand	25 "	110 "
(3)	Marl	11 "	122 "
	Quicksand	35 "	157 "
(4)	Marl (fourth stratum), at		170 "
	Sand, some clay	5 "	175 "
	Sand, some clay (*water good*)	2 "	177 "
	Sand	6 "	183 "
	(Cased to 179 feet.)		

"Isaac W. Stokes writes that 'the water is first-class, and rises to within seventeen feet of the surface,' and that 'the supply seems inexhaustible.'"

Quite recently I. W. Stokes again writes that "the flow (supply) continues unlimited and the water unsurpassed. Excellent."

The irony water noted at seventy feet probably came in large part, at least, from the greensands just above the shell crust that separates the Middle Marl from the red sand bed.

The water horizon at 179 feet, now utilized, is probably near the top of the clay marls.

ARTESIAN WELL TWO MILES EAST OF MARLTON, ON THE FARM OF BENJAMIN COOPER.

Elevation, 60 feet; diameter, 6 inches; depth, 77 feet. Water rises within 4 feet of the surface.

This well was recently brought to the writer's notice by J. W. Barr, who bored the same, and who states the depth to be 77 feet. This well was reported in the Annual Report for 1885, page 132, but its depth is there given at 70 feet. It is quite probable that the casing was driven to only 70 feet, and that the drill penetrated to the depth of 77 feet. The following, written by Prof. Geo. H. Cook, is taken from the report for 1885:

"At the farm of Benjamin Cooper, two miles east of Marlton, in Burlington county, an artesian well has been sunk, which supplies a large quantity of exceptionally-good water. It is located over the Middle Marl bed, but the water is evidently drawn from a sand bed underneath that bed of marl. The materials passed through, as reported by Mr. Cooper, are—

Upper soil	28 feet	= 28	feet.
Ironstone (sand and oxide of iron)	3 "	= 31	"
Greensand marl	1 "	= 32	"
Ironstone	1 "	= 33	"
Greensand marl, black and chocolate marl (no accurate account kept of each)	19 "	= 52	"
Clean black sand, with white specks	14 "	= 66	"
Stopped in open coarse sand [whitish], with belemnites	4 "	= 70	"
*[Water bearing sand	7 "	= 77	"]

"The well was tubed with a 6-inch pipe, and the water rose in it to within 5 feet 7 inches of the surface, and remained at that point until

*The words in brackets are introduced by the present writer.

the water was pumped freely, after which it rose to 3 feet 10 inches from the surface. The water is clear and soft, and of excellent quality for all household purposes. Its temperature is 54 degrees. Mr. Cooper has erected over the well a 12-foot turbine windmill. After running the pump for three days, with a good wind during the day, at no time was the water lowered more than three inches, though the pump was showing a steady inch stream."

In a recent interview with Benjamin Cooper we were informed that the level of the water, the temperature and the quality are still maintained. He also states that there is a difference in the quality of the water from the various wells near Marlton and Medford; that some of the wells have not been continued and cased deep enough, but were stopped within the above-described "black sand with white specks," which was entirely cased off in his well. This black sand, he says, does not furnish as good water as the whitish sand below it. In proof of the difference in character of the two sands and their influence upon the quality of their contained waters, he instances the fact that at the time of the occurrence of the earthquake, in the year 1884, the water in a well that was stopped in the *black sand* was made *inky*, while the water in his own well was made *milky* in appearance.

ARTESIAN WELL NEAR MARLTON, N. J., ON THE FARM OF AMOS EVENS.

Elevation, 70 feet; diameter, 5 inches; depth, 83 feet. Water rises within 7 feet of the surface.

Some years since a well was put down on the farm of Amos Evens, near Marlton.

The data at the heading above were furnished by W. C. Barr. The well draws from the same water horizon as the other wells in this region.

ARTESIAN WELL TWO MILES EAST OF MARLTON, AT THE RESIDENCE OF WILLIAM B. COOPER.

Elevation, 55 feet; diameter, 5 inches; depth, 77 feet. Water rises very near the surface.

W. C. Barr informs that he drilled a five-inch well at William B. Cooper's. This well is northwest of Benjamin Cooper's well a distance of one-eighth of a mile. In both wells the black sand with

white specks was met with and cased off. This sand is said to much resemble the black sand formerly used for sanding freshly-made writing before the introduction of blotting paper. In both wells the same depth of seventy-seven feet was reached and both furnish the same quality of especially-good water.

ARTESIAN WELL NEAR MARLTON, ON THE FARM OF WM. J. EVANS.

Elevation, 100 feet; diameter, 5 inches; depth, 121 feet. Water rises within about 20 feet of the surface.

W. C. Barr furnishes the following record:

Depth of well when boring commenced.......			24 feet.		Pleistocene.
Black marl..........	16 feet	=	40	"	Upper Marl(?)
White sand crust..........	10 "	=	50	"	Lime sand.
Black marl and shell..........	30 "	=	80	"	Middle Marl.
Green clay marl..........	6 "	=	86	"	
Chocolate mud..........	28 "	=	114	"	
Shell crust..........	3 "	=	117	"	Red sand bed.
Gray sand, *water*..........	4 "	=	121	"	

The water is obtained from the top of the "red sand bed."

ARTESIAN WELL SOUTH OF MARLTON, AT THE RESIDENCE OF BOWMAN S. LIPPINCOTT.

Elevation, 85 feet; diameter, 5 inches; depth, 105 feet. Water rises within 16 feet of the surface.

The boring of this well was commenced at the bottom of a dug well, with a depth of 18 feet. W. C. Barr furnishes the following record:

Depth of dug well..........			18 feet.		
Black mud..........	20 feet	=	38	"	
White sand crust..........	12 "	=	50	"	Lime sand.
Black sand marl..........	4 "	=	54	"	Middle Marl.
Ironstone crust..........	1 "	=	55	"	
Black sand..........	2 "	=	57	"	
Black marl..........	6 "	=	63	"	
Green clay marl..........	8 "	=	71	"	
Fine dark sand..........	2 "	=	73	"	
Chocolate marl..........	22 "	=	95	"	
Shell crust..........	3 "	=	98	"	Red sand bed.
Green sand..........	2 "	=	100	"	
White sand..........	5 "	=	105	"	

There were obtained from this bed, probably from the Middle Marl, numerous well-preserved though fragmentary specimens of *Terebratula*,* and a few small but perfect *Exogyra*.* From near the base were obtained a considerable number of fragmentary specimens of belemnites. The Bryozoa so characteristic of the lime sand over the Middle Marl bed were also seen among the specimens.

ARTESIAN WELL NEAR MARLTON, AT LEVI T. BALLINGER'S, ON THE ELMWOOD ROAD.

Elevation, 60 feet; diameter, 5 inches; depth, 82 feet. Water rises within 14 feet of the surface.

The following record was received from W. C. Barr:

Top soil and clay		15 feet.	
Gravel and quicksand	5 feet.	20 "	
Black marl and shell	25 "	45 "	Middle Marl.
Green clay marl	4 "	49 "	Middle Marl.
Chocolate marl	27 "	76 "	Middle Marl.
Shell crust and *belemnites*	4 "	80 "	Red sand bed.
White sand, *water*	2 "	82 "	Red sand bed.

A series of specimens of the borings was preserved by L. T. Ballinger. These showed, at the depth of 32 feet, indurated, irony, red-colored casts of *Gryphea* † and other shells. Attached to the casts were crystals of vivianite. This shell layer exactly resembles indurated casts of shells to be seen at Stratton's pits, near Mullica Hill. At 65 feet were some fragments of an oyster, not in a condition that would admit of determination. At 80 feet were fragments of belemnites.

ARTESIAN WELLS TWO MILES EAST-SOUTHEAST OF MARLTON, ON THE FARM OF JOSEPH EVANS.

Elevation, 129 feet. One successful well, diameter, 5 inches; depth, 155 feet; one unsuccessful well, depth, 365 feet

A successful well was put down within a few years, of which Richard Houseman furnishes the following record of materials passed through:

* Technically, *Terebratula Harlani* Morton, *Exogyra costata* Say.

† *Gryphea vesicularis* Lamark.

Sand	20 feet	= 0 feet	to 20 feet.		
Black loam or marl	50 "	= 20 "	" 70 "	Upper Marl (?)
Sand	14 "	= 70 "	" 84 "	Lime sand.
Crust	9 "	= 84 "	" 93 "	
Green marl	27 "	= 93 "	" 120 "	Middle Marl.
Sand	27 "	= 120 "	" 147 "	
Shell crust of oyster and other shells	2 "	= 147 "	" 149 "	Red sand bed.
White sand with water	6 "	= 149 "	" 155 "	

An unsuccessful boring had been made some years previously to a depth of 365 feet. Of this well we are furnished with the following general description of strata below the first 155 feet, to which depth the well above noted furnishes correct information:

Gray micaceous sand from	155 feet to 220 feet.	Clay Marls.
Blue clay—clay marl from	220 " " 365 "	

Large oyster shells were found at about 300 feet, and also sharks' teeth.

ARTESIAN WELL TWO MILES EAST OF MARLTON, ON THE FARM OF JACOB L. EVENS

Elevation, 60 feet; depth, 98 feet. Water rises within 6 feet of the surface.

There is a well on the property of Jacob L. Evens that obtains at the depth of ninety five feet a supply of exceptionally good water. From a series of specimens preserved by the owner the following data were obtained:

Yellowish marly sand	at 20 feet.	
" " "	" 25 "	
Sand, with *Bryozoa*	" 30 "	Lime sand.
Marl with *Terebratula*	" 40 "	Middle Marl.
" " *Gryphea*	" 45 "	
Belemnites = *Belemnitella*	" (65?) "	
Marl	" 80 "	
"	" 85 "	
"	" 90 "	
Water-bearing sand	" 98 "	Red sand bed.

The water rises within about six feet of the surface.

The *Terebratula* and *Gryphea* above noted were well preserved, nearly entire specimens retaining the shell in its original white calcareous condition. From the records of the other wells, the writer is inclined to think that the belemnites noted at sixty-five feet are wrongly marked, and were probably obtained at the depth of about eighty-five feet.

ARTESIAN WELL THREE MILES EAST OF MARLTON, BORED FOR A. W. LOFLAND, ON THE DAVIS ROGERS FARM.

Elevation, 60 feet; diameter, 5 inches; depth, 102 feet. Water rises within 7 feet of the surface.

While this report was in preparation the following record was received from W. C. Barr of a well put down at the above locality, which is about three miles east of C. B. Chew's well:

Top soil quicksand and pebbles	15 feet =	15 feet.		
Black marl	15 " =	30 "	Upper marl.	Cretaceous.
Stone crust and gray marl or lime sand	28 " =	58 "	Lime sand.	
Green marl	8 " =	66 "	Middle Marl.	
Chocolate marl	29 ' =	95 "		
Shell crust	5 " =	100 "	Red sand bed.	
Gray open sand and water	2 " =	102 "		

There were obtained from this boring the following fossils: *Bryozoa* from the lime sand, *Terebratula* from the Middle Marl, *Belemnitella* from the shell crust, *Pecten* probably also from the shell crust, and small but perfect *Exogyra*, the exact horizon or depth of which we have been unable to ascertain. The water obtained is of good quality, and rises within seven feet of the surface.

ARTESIAN WELL NORTHEAST OF AND NEAR MEDFORD, N. J., BORED FOR JOSHUA S. WILLS.

Elevation, 63 feet; depth, 126 feet. Water rises within 25 feet of the surface.

This well, which was bored by Stothoff Bros., was reported last year, but as some additional information has since been received, it is again noticed.

This well is upon the farm of Joshua S. Wills, about one and three-quarter miles northeast of Medford station. A set of borings was exhibited for awhile in a drug store at Medford, and afterwards forwarded to the writer through the recommendation of a geological friend who chanced to see them, and who rightly appreciated the value of the specimens to the Survey.

By correspondence with J. S. Wills, the elevation of the surface is learned to be sixty-three feet. After careful examination of the various specimens the following record has been made:

Specimen.					
No. 1.	Soil	2 feet.	2 feet.		
2.	Clay, yellow sand	3 "	5 "		
3.	Fine gray sand with greensand grains		5 to 15 "		
4.	Coarse gray sand with greensand grains		15 to 23 "		
5.	Olive-colored marl, at		30 "		
6.	Dark-green marl, at		35 "	Bottom of Upper Marl.	Cretaceous.
7.	Lime sand and foraminifera, *Bryozoa*, at		50 "	Lime sand.	
8.	Green marl with shell *Gryphea* and *Terebratula*, at		70 "	Middle Marl.	
9.	Pure greensand, dark color, at		76 "		
10.	" " light color, at		80 "		
11.	" " dark color, at		91 "		
12.	" " chocolate color, at		104 "		
13.	" " dark green, at		120 "		
14.	Gray sand with greensand grains and shell, &c., *Exogyra* and belemnites, at		124 "	Red sand bed.	
15.	Gray sand and *water*, at		126 "		

This water rises to within 25 feet of the surface.

J. S. Wills writes that "water was found at the depth of seventy feet, but that it was not good, and that after reaching the depth of 127 feet we had an excellent flow of good water."

In the Annual Report for 1892, page 302, and also in this volume, page 210, a record is given for a well bored for Isaac W. Stokes, one and one-half miles almost due northwest on ground elevated about seventy-eight feet. The relative position of these two wells is almost directly across the line of strike of the strata. I. W. Stokes' well, as stated last year, was deepened from a water horizon at about seventy feet to one at 175 to 183 feet. A comparison of the records and specimens of the two wells shows conclusively that the upper water horizon at sixty-four to seventy feet in I. W. Stokes' well is the same as that at 126 feet at the bottom of J. S. Wills' well.

The water of inferior quality noted above at seventy feet represents, of course, a still higher horizon. J. S. Wills also remarks that "the different strata we went through are very similar to those passed through by Joseph Evans." (See page 214.) This latter well is located six and one-half miles west-southwest. The distance between two parallel northeast and southwest lines of strike drawn through the two wells is one and one-tenth miles. The shell bed in Joseph Evans' well, at 147 to 149 feet (see page 214), is the equivalent of that in J. S. Wills' well at 120 to 124 feet. Making allowance for difference in elevation of the surface, a calculation shows this shell

bed to dip slightly over thirty-seven feet per mile. The section for this region is constructed on a basis of thirty-seven and five-eighths feet per mile, that amount of dip being the average presented by the various wells and harmonizing best all the conditions.

ARTESIAN WELL IN MEDFORD, N. J., AT THE RESIDENCE OF JOSEPH HINCHMAN.

Elevation, 60 feet; diameter, 3 inches; depth, 150 feet.

About five years since a well was put down in Medford at the residence of Joseph Hinchman, who has furnished information from which the following record has been compiled:

Soil and gravel	12 feet.	12 feet.	= Pleistocene.
Clay	5 "	17 "	= Miocene (?).
Marl	35 "	52 "	= Upper Marl.
Blue clay	5 "	57 "	
Lime sand	16 "	73 "	= Lime sand bed.
Then alternation of sands, marls, gravels, &c., to		150 "	= Middle Marl and red sand bed.

Belemnites near the base.

Water was found at 17 feet, at 90 feet, and at 140 feet. The water at the lowest horizon only was utilized; this rises to within about 18 feet of the surface. The well is cased to the depth of 140 feet, though the boring was continued to that of 150 feet. By reference to the section, it will be seen that this well draws from the same horizon as the other wells in the region of Marlton and Medford.

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SUPPLEMENT TO REPORT ON ARTESIAN WELLS.

ARTESIAN WELLS AT PLAINFIELD.

P. H. & J. Conlin inform that they have sunk four wells for the Plainfield Water Works. The average depth is about fifty feet. Clay was found at about eight feet from the surface, below which fine quicksand was encountered to a depth of forty feet, at which depth occurs a coarse water-bearing gravel.

"The first well was tested alone and produced on twenty-four hours' test 750 gallons of water per minute. The others were tested collectively and produced a similar quantity. These wells had peculiar strainers put in them, as previous wells put down had to be renewed on account of the sand getting in the strainers and clogging them."

P. H. & J. Conlin also furnished samples of strata from wells Nos. 3 and 4.

The water-bearing gravel, and especially the clay overlying it are decidedly reddish in color and have evidently been derived from the Trias. Many of the pebbles in the gravel are as large as walnuts and butternuts, and are more or less rounded and water-worn. Most of them are apparently made from Triassic shales and sandstones, though among these are a few of trap-rock, some of which show amygdaloidal cavities.

ARTESIAN WELLS AT NEWARK AND VICINITY.

P. H. & J. Conlin forward the following account of various wells put down by them at Newark and vicinity:

"At C. Roberts & Co. Rubber Works, Newark, well 8 inches in diameter. Struck rock 20 feet from surface. Drilled into rock 200 feet. Well produced, on pumping, 50 gallons of water per minute. The rock was of the red shale formation."

"Herold Smelting and Refining Co., situated on the meadows, about half way between Newark and Waverly. The first 20 feet was black mud, then alternate layers of clay and quicksand. Clay beds did not vary over one foot in thickness. Rock was struck at a depth of 175 feet from the surface; the balance of the well, to the depth of 220 feet, is drilled through red shale. Well produced, on twenty-four hours' pumping, 100 gallons per minute."

"At Smith's tannery, Newark, we drove well to a depth of 195 feet. Nothing but clay, intermingled with fine sand, was met with. At the above depth a water-bearing gravel was found, and produced, on ten hours' test, 60 gallons of water per minute."

Smith's tannery is one-half mile from the meadows adjoining Newark, and one-half mile from the Herold well, the latter well being the farthest out.

"The Newark Licorice Works has a 10-inch well. Rock was encountered at about 32 feet from the surface. The rock is of brown sandstone character, of hard quality. Well 220 feet deep. Well produced, on ten hours' continuous test, 150 gallons of water per minute."

"At W. Englehart's residence, Harrison, N. J., we sunk a well to a depth of 127 feet. From surface to water-bearing strata nothing but fine sand. There was a moderate supply of water found."

Harrison is on the opposite side of the Passaic from Newark. This well and the wells above noted at Smith's and Herold's are all located upon practically the same meadow land.

ARTESIAN WELLS IN NEW YORK CITY, BROOKLYN, AND VICINITY.

P. H. &. J. Conlin report as follows:

Wells in New York City.

"In New York City we drilled a well for the Manhattan Life Insurance Company. Rock was encountered at fifty-five feet from cellar bottom. The formation of rock was granite. There was no visible supply of water until a depth of 800 feet was reached. At that depth a small supply was found. At a depth of 1,056 feet the well produced on seventy-two hours' continuous test seventy-five gallons of water per minute."

Wells in Brooklyn, N. Y.

"Ten wells, put down for the city of Brooklyn on Long Island, fine sand was met with from surface to a depth of sixty feet, at which depth a water-bearing stratum was found. The wells produced collectively five million gallons of water per twenty-four hours."

This boring is evidently either in glacial morainic drift or in the overwash plain on the south side of Long Island.

Well at Noroton, Connecticut.

"We have drilled two wells in Connecticut on the sound near Noroton. Drilled one to a depth of 700 feet, but no water. Drilled another well about half a mile from first one; we are down about 900 feet, with only four gallons per minute; the formation of rock is granite; we expect to drill the wells deeper in the spring, with the expectation of getting the needed supply. The rock has not changed in character from the surface. We have drilled several other wells in Connecticut with very good results."

Wells at Mount Vernon, Port Chester and Whitsons.

"We have drilled wells in Mount Vernon, Port Chester, Whitsons, &c., all within thirty miles from New York City. They are all in close proximity to the Long Island Sound. Rock was met with not over five feet from surface, and was of granite formation. The wells varied in depth from 100 feet to 300 feet."

PART III.

FORESTRY.

REPORT OF PROGRESS.

REPORT ON FORESTRY.

In accordance with a supplementary act of the Legislature, passed at its last session, and approved May 1st, 1894, the State Geologist, under the direction of the Board of Managers of the Geological Survey, (1) "shall make an investigation to ascertain the extent, character and location of the wild lands of the State which are suited for permanent occupation by forests rather than by agriculture," and (2) "shall report the results of such investigation to the Legislature, together with a statement of what part or parts of such lands would be suitable for a State forest reserve," and (3) "the advantages as regards the timber-supply, water-supply, scenery and climate of the State which would accrue from the conservation of existing forests by the establishment of such reserve, or otherwise;" (4) "the investigation so to be made shall determine the extent to which forests of timber of commercial value now exist in the State, and include a study of the localities and areas which are specially adapted to the growth of designated kinds of timber of commercial value;" (5) "it shall also include an examination as to the presence or absence of forest cover upon the slopes and summits of the more important watersheds of the State, and a study of the effect of such conditions as now exist upon the maintenance of the streams therein and the regulation of the freshets thereof;" (6) "the report to the Legislature shall state the arguments touching the beneficial effect upon climate and rainfall attributable to the presence of forests, and shall likewise present an outline of the policy and legislation of other States and countries for the preservation of forests and their regulation for public ends, so far as the same may be applicable to this State."

The work indicated in this legislative enactment may be summarized under the following heads:

1. A survey to ascertain the extent, location and character of the "wild lands" or forest lands of the State, and the advantages of their retention in forest.

2. A survey of the more important water-sheds or drainage basins and their forested areas, with reference to the protective measures needed to save this forest cover and thereby maintain the purity of the water, as well as promote the more equable flow of the streams.

3. A study of the relations of forests as climatic factors, and particularly to the rainfall.

4. A compilation of the forest legislation in other States and countries in so far as it may be applicable to conditions in New Jersey.

From the standpoint of our present knowledge of the forested lands in the State, the following large divisions are recognized:

1. Kittatinny mountain.
2. Kittatinny valley and the valleys in the Highlands.
3. The Highlands.
4. The Red Sandstone plain.
5. The Southern-Central belt.
6. The Southeastern or Coastal belt.

In this scheme the Upper Delaware valley is not given, except as it is included in the Kittatinny mountain slope to the Delaware. The trap-rock ridges also are omitted, as they constitute an inseparable part of the Triassic or Red Sandstone belt. The coastal-dune range or sea-beaches also are omitted, inasmuch as the forest on them is of inconsiderable extent, and is destined to give way to the growing towns and seaside resorts.

The large forested areas of the State which are of sufficient extent to deserve consideration as forest reservations are in the southeastern belt, and in the Highlands and on the Kittatinny mountain. In the Kittatinny and other northern valleys the percentage of area not cleared and in farms is comparatively small, and the wood-lots are the property of individual farm-owners.

In the Red Sandstone plain there is little woodland, excepting on the trap-rock ridges, which are largely wooded. Deforestation has gone too far in some parts of this belt, and the effects of the general clearing are seen in the torrential character of the streams and in the sweep and destruction of the winds.

In the marl and clay belt—or as above named, the southern-central belt—there is a fair proportion of forest to farm land, and the

distribution is favorable to the preservation of equable climatic conditions. Nearly all of the woodland in this belt, as in the Red Sandstone belt and in the Kittatinny valley and the Highlands valleys, is in small lots or tracts and in farms. As thus locally distributed, it is valuable for domestic or home consumption, and is not of extent to command attention or public consideration as a part of a general forest reservation under State control. The possible exception to this general statement is in that class of valley slopes in the Highlands drainage basins, where the character of the stream-flow may be affected injuriously by the too general clearing of these lands, and the exposure of the steeply-sloping surface to the wash of the rains.

The survey of the forests in the more wooded divisions of the State includes the gathering of statistics of forest fires and the study of ways in which the destruction of valuable timber lands may be averted, and the obstacles to profitable timber-culture be set aside. The problem of public care of the woods and the prevention of fires must be investigated and solved for the southeastern or pines belt, and also in the Kittatinny mountain range. In the Highlands the dangers are not great, and the ownership control is fairly efficient in protecting its forests. In the other belts this question is not of importance, on account of the small size of the wooded tracts, their distribution among the cleared areas and their isolation. The individual owners of the many small lots care for them and protect them against the ravages to which large tracts are more exposed.

The importance of timber-culture or the value of wood as a crop, and the climatic relations of forests, are broad questions, which are not limited to belts or topographic divisions of the State, but are applicable to all. These questions affect the agricultural economy of the State also, and are therefore of general interest to the rural population. The farmer is interested in wood-growing and in the climatic conditions favoring good crops. The cities also are affected favorably or unfavorably, since they are exposed to the sweep of these forces, which dominate both town and country.

REPORT ON FORESTRY IN THE NORTHERN PART OF THE STATE.

BY C. C. VERMEULE.

During the past autumn surveys and examinations have been made of the forests of the northeastern part of the State, including practically the Highlands and Red Sandstone plain, between the New York line and a line drawn from the head of Newark bay through Boonton to Ogdensburg. The work included a survey of the outlines of all areas of forest of sufficient size to be shown on a scale of three inches to the mile. The inquiries covered the size and quality of the growth, classed as follows:

1. Brush or stump land, to include no areas intended to be cleared and cultivated.
2. Old clearings formerly cultivated, but now growing up to timber.
3. Young growth, in which class was included all timber less than six inches diameter, the approximate age, size and height being noted.
4. Large timber, including all over six inches in diameter, the diameter and height being noted as before.

Without attempting any strict botanical classification, the varieties of timber have been designated as follows:

1. Deciduous, with the prevailing varieties indicated.
2. Coniferous, classified as pine, cedar, hemlock, &c.
3. Mixed deciduous and coniferous.

Notes were kept of the general character of scattered growth over lands under cultivation, also of the general condition of the forested areas, and of any remarkably large trees, any original forest, planted timber, brush land which seems incapable of producing timber, the

succession of growth, &c. Information was also collected as to the product of saw-mills, kindling-wood factories, &c., and notes were made as to the value per acre of stump land of twenty-year or thirty-year growth, and all heavy timber of various kinds; also of the testimony of reliable persons as to how the amount of timber now standing compares with that of previous periods, and of how the growth on slopes of hills compares with that in the valleys or on the top of plateaus.

It will be noted that the inquiries were of the most practical kind, and it is believed that the information obtained will be of value in reaching an understanding of the actual economic condition of our forested areas. Thus far they have developed the fact that there have been no important changes either in the limits of cultivated land, or in the proportion of forested and cultivated areas, since the topographical surveys were begun in 1877. There have been minor changes, and a few old clearings of small area have been allowed to grow up, the areas thus added to the forests being just about offset by that which has been brought under cultivation, likewise in small, scattered parcels.

The topographical maps showed forested lands as distinguished from those under cultivation. They made no attempt to indicate the varieties, size or condition of the timber. There is very little land in the State which, if left uncultivated, does not spontaneously produce, in a few years, a fairly good growth of timber; consequently, the land represented as forest on the maps, for which the surveys were completed in 1887, range from brush to good timber, of from forty to fifty years' growth, and for the most part every gradation of growth is represented in due proportion. The examinations made during the past year have attempted to differentiate this growth into varieties of trees, age and size, as we have explained.

Like almost every other physical feature of the State, the forests may be classed broadly into five divisions corresponding with the geological formations, and each of the three northern divisions must be subdivided into glaciated and unglaciated districts. There is a marked difference in the proportion of forest area, and also a less marked difference in the varieties of timber north and south of the moraine line. Consequently we can most conveniently consider the forests by the several topographical divisions adopted and followed in the "Physical Description" of the State, published in 1888.

PALISADES MOUNTAIN.

It will be a surprise to many to learn that this ridge, so near to the large cities and in the most populous section of the State, is so well wooded. From the State line south to Edgewater, a distance of thirteen miles, and for a width of one and one-half miles back from the bank of the Hudson, practically 90 per cent. of the whole area is well timbered. The forest covers an unbroken tract of 11,000 acres. Beginning at the State line and extending to one mile below Huyler's landing, we have, on the talus slope along the river, a mixed deciduous growth, mainly chestnut and oak, from thirty to sixty feet high, varied with pine and hemlock near Huyler's landing We give here, as elsewhere, only the prevailing timber, but in reality this whole Palisades forest includes a large number of varieties. Further down to Linwood the growth on the talus is more irregular, containing a fair proportion of oak and chestnut of good size, with scattering hemlock. From Linwood to Fort Lee the talus is well wooded, some good white pine being found, but oak and chestnut prevail. From Fort Lee to Edgewater the river slope of the ridge is well timbered, but a strip of land along the river at the foot has been cleared and occupied by residents. On the flat top and upper portion of the western slope of the mountain from the State line to Edgewater, if we except some red cedar near the State line, the growth is practically of mixed deciduous varieties, mostly oak and chestnut. This timber ranges from undergrowth to trees forty, sixty and eighty feet in height. Diameters of from twenty to thirty inches, and heights of from sixty to eighty feet, are not at all uncommon, especially from Huyler's landing to Edgewater. Taken as a whole, there are not many finer belts of timber in the State. The land is largely held in such a way that there is comparatively little danger of wholesale deforesting, but this beautiful forest has almost as good a claim to future preservation as the escarpment of the Palisades. South of Edgewater the ridge is practically a city to Bergen Point, and entirely deforested.

HACKENSACK VALLEY.

The Red Sandstone country lying between Palisades mountain on the east and Ramapo and Orange mountains on the west, was designated by us, the Hackensack valley, in the "Physical Description." Topograph-

ically it is all one valley, although not all drained by the Hackensack river. It includes all of Bergen and Hudson counties, Passaic county southeast of Paterson, and the northeastern corner of Essex county. It contains a large urban and suburban population, and it seems somewhat anomalous that it should also include some of the best timber of the State. The valley as a whole has 30 per cent. of its upland area in timber, or, in other words, 61,000 acres in a total of 180,000 acres of upland. Bergen county has 39 per cent. in timber, Hudson county only 5 per cent., the Passaic county portion 9 per cent., and the Essex county portion 20 per cent. In topographical position this timber is largely confined to the slopes, level valley bottoms and plateaus being mainly under cultivation. These cultivated portions, however, have a very liberal allowance of scattering forest trees, orchards and other planted trees, so that in looking over the valley from an elevation it appears to be very generally wooded. The really forested portion ranges through all conditions, from a very limited amount of brush and stump land to heavy timber. Very little of it is now cut off entirely, most of the cutting being selected trees, so that the considerable amount of timber taken out each year is scarcely missed. There is no wastefulness apparent as a rule in the handling of the forests. It is generally a mixed deciduous growth, with oak predominating in the lower land along the Hackensack, while chestnut prevails on the higher ridges westward, and softer woods, such as gum, white birch, beech and maple in the swamps. Here and there are a few scattering hemlocks. From Closter to Englewood there is much red cedar. The timber is usually in rather small, isolated areas not often reaching 100 acres in extent. There is a tract of some 500 acres along the Hackensack near the State line. Proceeding southward from the State line across the whole width of the valley there is a gradual decrease in the amount of timber. The growth in the vicinity of Ramseys to Wyckoff is rather mixed, consisting of oak, chestnut, maple, beech, elm, white birch, red cedar, &c., in all stages of growth, from brush to trees eighty feet in height, but there is a notable absence of stump land or new clearing. Near Paterson the country is quite deforested, the 9 per cent. of forest in the Passaic portion of the valley consisting mainly of small patches of oak and chestnut, preserved in connection with farms, and only cut occasionally and sparingly as needed. Most of the groves contain much fine timber, and are generally well cared for. Proceeding

southwest into Essex county the wooded area is increased to 20 per cent. and is somewhat similar to that described, although the timber is, as a rule, not so good. There are some quite large timber areas north of Belleville. In this Hackensack valley, as a whole, the timber is probably as well cared for as in any other equally large section of the State. It is thrifty and healthy, and suffers comparatively little from fires.

The value of the land here is, of course, generally much too high for profitable forestry. In most well-located places it is worth from $400 to $1,000 per acre where it is still sold by the acre instead of by the foot. In a few out-of-the-way places it ranges lower, but is in any case largely independent of the character of the timber. From inquiry it was estimated, however, that the timber alone was worth from $30 to $50 per acre for a thirty-years' growth, and in proportion for younger timber, but old timber of mixed varieties is worth from $100 to $150 per acre. Swamp land timber is said to be rarely worth more than $20 per acre. In the vicinity of Wyckoff we obtained the following general prices: Swamp land, $5; twenty-years' growth, $15 to $25; thirty-years' growth, $25 to $35; large oak and chestnut, $75 to $100 per acre. About Oakland, stump land, $3; twenty-years' growth, $20; thirty-years' growth, $30; large mixed growth, $60. In such inquiries as this it becomes quite evident that many of the estimates given are based on the prevailing rule that timber will produce one cord of wood per acre for each year that it is growing, and that this wood is worth about $1 per cord on the stump, as was determined by a large number of written inquiries sent out by the Survey, the results of which were published in the Annual Report for 1885. This rule seems to prevail all over the State, but it is quite evident that it cannot be equally fair for all sections, although probably a good working average.

A few tracts claimed to be original forest were noted in the Hackensack valley. One is half a mile east of Hillsdale, containing about thirty acres of oak, fifteen to twenty-eight inches in diameter and about seventy feet high; a small piece of oak one-half mile south of Rivervale, another, one mile west of Englewood, containing oak from fifteen to thirty inches in diameter and from sixty to eighty feet high, and another piece of oak, one mile northwest of Oradell, on the ridge. It is noticeable that all of these tracts are of oak.

Several large trees were noted throughout the valley. At Hoho-

kus, a fine elm fifty inches in diameter and eighty feet high, with a spread of branches of about 100 feet; one mile southwest of Etna, an oak forty-six inches in diameter and sixty feet high; in an old clearing one mile northeast of Saddle River, two chestnuts each sixty inches in diameter; on the estate of the late Hon. W. W. Phelps, at Teaneck, two oaks forty inches in diameter; at Ridgewood, a chestnut sixty inches in diameter; at Haworth, a chestnut eighty-four inches and another seventy-eight inches in diameter; north of Arcola, a chestnut seventy-two inches in diameter; at Overton, a chestnut seventy-six inches in diameter. Most of these chestnuts are only remarkable for girth, but near Oradell there is a fine chestnut tree sixty-three inches in diameter and fifty-five feet high; at the forks of the road, a little over one-half of a mile north of Ramseys, a chestnut sixty inches in diameter and fifty feet high; another, three-quarters of a mile northwest, sixty inches in diameter and forty-five feet high. Near Campgaw we noted a chestnut sixty-two inches in diameter and sixty feet high, and two others sixty-six inches in diameter and fifty and sixty feet high; north of Wyckoff, a large whitewood thirty-six inches in diameter and eighty feet high; near Wortendyke, a chestnut forty-eight inches in diameter and sixty-five feet high. Near Paterson chestnuts were noted thirty-six to sixty inches in diameter and sixty feet in height; also, two large black walnuts, near the river, northeast of Paterson, forty-two inches in diameter and sixty feet high. The total consumption of saw-mills in this district was ascertained by inquiry to amount to practically 2,400,000 feet, board measure, of lumber, and besides this kindling-wood factories consumed the timber from about twenty-five acres annually. The whole consumption by these mills would therefore probably not exceed the growth from eighty-five acres annually. Besides this use, however, there is the consumption for railroad ties, telegraph and telephone poles and fuel, the amount of which has not yet been ascertained.

As regards the succession of growth, the general opinion seems to be that it is of the same kind as that cut off, although some claim that white oak and hickory are followed by a more mixed growth. It is evident that since the cutting off entire of areas of timber seems to have been long ago abandoned in this vicinity, and that most of the cutting is, as we have remarked, by culling out, there cannot be much reliable data obtained on this point. At Moonachie, maple is

said to have succeeded oak, and at other places the succession has been chestnut. There is no room for doubt, however, that as a rule abandoned clearings grow up in red cedar, although this is occasionally accompanied by, or replaced with, white birch.

Groves of planted white pine may be seen on the estate of the late William Walter Phelps, and also one mile east of Saddle River, south of the road from Ridgewood to New Milford.

WATCHUNG MOUNTAINS.

The detailed surveys have extended over the trap ridges above Campgaw, Goffle and Preakness mountains, and the First and Second mountains southward to Caldwell and Verona. North of Campgaw there is an unbroken tract of about 2,000 acres of timber covering the trap hill. It is principally chestnut and oak, about fifty feet high and from six to twelve inches in diameter in the northern portion, and from twenty to forty feet high and three to eight inches in diameter in the southern part. From Campgaw, by Sicomac to the Goffle, the timbered areas are more scattering and also more varied in character, but oak and chestnut are still predominant. Over all these trap ridges red cedar prevails, springing up spontaneously and persistently in abandoned clearings. It is generally less than twenty feet in height. The Goffle has some good oak and chestnut timber fifty to seventy years old, from fifty to seventy feet high and ten to fourteen inches in diameter. On Preakness mountain and the ridge just west the growth is largely mixed with red cedar, and is of an inferior size and quality on the trap, being much better on the red sandstone portion of the eastern slope near the foot. Near Pompton lake there is considerable good hemlock, this last being a rather unusual growth for this part of the State. Second mountain about Caldwell and northward has some fair oak, chestnut and hickory. First mountain is not so well timbered, and has more red cedar. Abandoned clearings are quite frequent, and the whole of the growth is irregular and patchy. Most of the timber is also younger than that in the Hackensack valley. There is a noticeably greater prevalence of hickory on the trap than on the red sandstone. In general, it may be said that the timber on the trap is decidedly inferior. This whole region of trap ridges has from forty to sixty per cent. of its area in forest, and there is a tendency to increase all forest areas.

PASSAIC VALLEY.

Detailed surveys have only covered Pompton plains and the township of Caldwell in this valley. Pompton plains is the most sparsely-wooded section of the valley. Generally the proportion of forest area is from twenty to forty per cent. Oak from ten to twenty inches in diameter and sixty to eighty feet high is common enough to indicate the ability of the soil to produce heavy timber, but the prevailing growth is much younger and lighter. It is quite irregular both in size and variety. The softer woods, such as gum, maple, willow, &c., prevail in the wet land. The valley has a large number of scattering trees, planted forest trees, fruit trees, &c., over its cultivated portions, and most of these trees are of large size, so that a general view from any commanding point gives the impression of a well-wooded country. Riker hill and Hook mountain contain timber similar to that of the Watchung mountains, with a large amount of red cedar. Swamp-land timber is estimated to be worth, on an average, about $50 per acre, and upland $100, if mostly oak and hickory. Stump land is valued at from $20 to $40 per acre, but this estimate evidently does not consider swamp lands, which are less, if the timber is cut off. As in other portions of the State, the prevalent tendency is to estimate for thirty years' growth a yield of thirty cords per acre, and about one cord per acre for each year that the timber has been growing. We may here remark that observations seem to indicate that most of the timber grows less rapidly after reaching about thirty years old, and generally for the northern part of the State the largest yield is obtained by cutting at about this age, especially if the growth is largely chestnut.

HIGHLANDS.

In the Highlands the detailed surveys have covered practically the water-sheds of the Pequannock, Wanaque and Ramapo rivers. The percentage of area in forest ranges from sixty to eighty, and generally averages about 75 per cent.

The plateau bounded by Bearfort mountain, the New York line, Vernon valley, and the New York, Susquehanna and Western railroad has about 80 per cent. of its area in timber, consisting mainly of oak and chestnut, a considerable portion of which is from thirty-

five to forty years old, and only a few acres older, the remainder being younger, ranging down to five or ten years. The growth from thirty to forty years old ranges from six to ten inches in diameter, and from thirty-five to forty-five feet in height. The more accessible portion of the timber is said to be cut at twenty years. Timber is believed to grow as rapidly as in earlier years. The only wastefulness apparent in cutting comes from the tendency to cut at too early an age, and this practice seems to be just about at the point of reform owing to a change in demand for hoop-poles and cordwood, so that there is likelihood of future improvement. The swamp areas indicated on the topographical maps on this plateau are generally wooded with maple, beech, elm, and occasionally with scattered pines, larches and white cedar. A dense growth of rhododendron makes some of the swamps very dark and almost impenetrable. Forest fires sometimes give trouble, and a large area east of Canistear, near Bearfort mountain, was burned over during this year. On this same plateau, southwest of the railroad at Stockholm, the condition of the timber is quite similar to what we have already described for the first two or three miles, but farther southwest the timber is older and larger.

Chestnut is said to generally succeed all other growth, accompanied by a considerable percentage of oak. Pine is said to have been succeeded by oak and chestnut. The eastern slopes of the hills are thought to produce the best timber, especially near the foot, while the extreme tops also often produce good timber. This is attributed to greater depth of soil. Pochuck mountain, lying just west of this plateau, does not differ from it materially, excepting that there is more hemlock and a somewhat thriftier growth. It is also not quite so densely wooded. Over the cleared portions the scattered growth is usually oak and chestnut, with some red cedar, maple, black walnut, &c. All these trees are of good size, the cedars from eight to twelve inches in diameter and forty feet high, and the other varieties from twelve to twenty-four inches in diameter and averaging about forty-five feet high.

In noting large trees here, as elsewhere, no attempt was made to include them all, the purpose being rather to indicate about what could be seen in passing over the country, and the capacity of the soil to produce good timber. Four chestnuts were noted, ranging from forty-two to sixty inches in diameter, and from forty to sixty feet high,

mostly near Stockholm and along the road to Vernon. The following oaks were also seen on Pochuck mountain: One, one-quarter mile west of Sand Hills, forty-eight inches in diameter and sixty feet high; another, one mile north, thirty-six inches by sixty feet, the spread of branches being forty feet. In Vernon there is one forty-two inches in diameter by fifty feet high, and three miles north of Stockholm another oak was seen thirty inches in diameter by forty-five feet high. An elm one mile north of Stockholm measured thirty inches by fifty feet, and another northwest of Vernon thirty inches by sixty feet. A maple was seen on Pochuck mountain thirty-six inches by seventy feet; two east of McAfee, in the valley, about thirty inches by fifty feet; two south of Vernon, about half way to Stockholm, about forty-eight inches in diameter by fifty and sixty feet high. Black walnuts were noted as follows: One, one-half mile east of Vernon, along the valley road, thirty-six inches by fifty feet, said to be one of the original forest trees. At McAfee there is one sixty-six inches by eighty-five feet. On the side of the mountain southeast of McAfee there is an apple tree measuring thirty-six inches in diameter by forty-five feet high, which is said to be the largest in Sussex county. Two miles southwest of Vernon, on the road to Stockholm, an oak and a walnut have grown together. At the base their combined diameters are forty-eight inches; above the junction each is about twenty-four inches in diameter.

The following was obtained as average values of timber near Stockholm: Stump land, $2; twenty-years' growth, $7; thirty-years' growth, $10; heavy chestnut or mixed oak and chestnut, $80. Heavy oak is said to be extremely scarce, but is quoted at from $60 to $100 per acre. At Vernon, stump land, $2; twenty-years' growth, $7; thirty-years' growth, $12; heavy chestnut or mixed oak and chestnut, $80. There is said to be very little valuable pine. At McAfee, stump land, $3; twenty-years' growth, $7; thirty-years' growth, $10; heavy chestnut and oak, $75 to $80. At Canistear, stump land, $3; twenty-years' growth, $10; thirty-years' growth, $15; heavy chestnut, $60.

On Bearfort mountain timber has suffered much from fires. In 1882, during the prosecution of the topographic survey of that section, a fire ran over a large area south of the road from Greenwood lake to Wawayanda, and this fire did injury from which the forests have not yet recovered. A fire in 1891 ran over most of the moun-

tain tops from the State line to Cedar lake. The timber is generally, both on account of these fires and the thinness or entire absence of soil over much of the mountain, scattering and of little value on the high ridges, but owing to its inaccessibility there has always remained a considerable amount of original forest, and in 1882 there was some quite heavy timber in the ravines, notably in the one heading at the westernmost of the two small ponds near the State line. This ravine was then heavily timbered, and travel through it was difficult, owing to fallen tree trunks. It was a good example of virgin forest. But, generally speaking, over the mountain tops the growth is scattering and inferior, which condition has been much aggravated by the recent fires referred to. There is a good deal of the common pine and some hemlock scattered over the mountain. The best timber is along the eastern slope, although this is all second growth; but the present growth is from thirty to forty years, eight to ten inches in diameter, and forty to forty-five feet high. It is mainly oak and chestnut and scattering pine and hemlock.

Green Pond and Copperas mountains are mainly covered with a forty-years' growth of oak and chestnut, rather sparse and poor on the top and eastern face, where the soil is thin, but fairly good on the western slopes, being there generally from eight to twelve inches in diameter and thirty-five to forty-five feet high. As on Bearfort mountain, there is a sprinkling of common pine. Some lots, aggregating perhaps 150 acres, have been cut off within from ten to fifteen years, but the remainder, if recently cut at all, has been only thinned out.

Bowling Green mountain south of Milton is largely covered with about a sixty-years' growth of oak and chestnut, averaging about twelve inches diameter and forty-five feet high.

The valley at Milton and Oak Ridge contains most of the cultivated land of this region, but about one-third of its area is in timber, mainly oak and chestnut of all ages from fifteen to sixty years, with a little pine along the road south of Clinton, and some maple and other soft woods in the low grounds. It is noticeable that all the principal slopes about this valley, and generally on the upper Pequannock water-shed, are well timbered. The valley has a considerable number of scattered trees over its cultivated portion, mostly from eight to twelve inches in diameter and forty to fifty feet high. The large trees noted were a black walnut, three-quarters of a mile west

of Milton, thirty inches by fifty feet; a red oak, one-quarter of a mile north of the same place, thirty-six inches by forty feet, and another, near Upper Longwood, sixty inches by sixty feet. From Petersburg to Upper Longwood, along the road, there are from twenty to thirty oaks and maples, ranging from twelve to twenty-four inches in diameter and averaging forty-five feet high. A maple east of Oak Ridge measures thirty-six inches in diameter by fifty feet high.

The portion of the Highlands lying between the valley running from Greenwood lake to Newfoundland, and Wanaque and Passaic valleys, was designated the Passaic range, in the "Physical Description." A portion of this, north of Pequannock river, has 75 per cent. of its area in forest, the central belt of the range being almost unbroken by clearings. In the northern part there is a considerable amount of oak and chestnut, from thirty to forty years old, including, perhaps, one-quarter of the whole region, while another large tract appears to exceed forty-five years in age, all the more accessible portions near Wanaque valley and the Pequannock being young growth of all ages from three to five years and upward, with very little stump land and no new clearing. It is evident that the practice of cutting at twenty years or younger has prevailed for several years along the lower Pequannock, and it would appear that the forest has suffered injury in consequence. This young timber seems to have been mainly cut for charcoal, firewood, hoop-poles, &c. While the timber is mostly oak and chestnut, there is some pine and hemlock between Macopin and West Milford, also red cedar in old pastures, and some white cedar south of Greenwood lake. The only portion of consequence which seems to have suffered from fire is an area of perhaps 150 acres along the Greenwood Lake railroad, just east of the lake. Most of the eastern part of this section is owned by Cooper & Hewitt, being a part of the Ringwood tract, and the forests of this part seem to be steadily improving. There is some new cutting about Hewitt, two or three hundred acres of stump and brush land being noted, and also some considerable areas of young growth of all ages. On this Passaic range, southwest of Pequannock river, our surveys have extended to a line drawn east and west through Denmark and Split Rock ponds. Chestnut and oak prevail here also, being mostly from thirty to forty years old, but with some younger parcels between Charlottesburg and Marcella, and also between Bloomingdale and Brook Valley. The latter portion is also somewhat mixed with

cedar, white birch, &c. There is little brush or stump land to be seen and not much timber less than ten years old. A tract of several thousand acres about Stickle pond is now held as a private preserve, and its forests are cared for.

In Wanaque valley, although the timber is more interspersed with clearings, it does not differ from that already described, excepting that there is more red cedar, which is probably due to the fact that the land has been some time cleared.

Ramapo mountain is practically an unbroken forest, mainly oak and chestnut. The main ridge from Negro pond south to the highway crossing from Midvale is covered with a good growth of perhaps thirty to forty years old, and most of the flatter portions of the mountain are likewise well timbered. Perhaps one-third to one-half of the slopes are not so well timbered, owing to thinness of soil. The southern end of the mountain is mostly covered with quite young timber and brush, and the timber on most of the more accessible parts has been cut within twenty years.

Generally the Passaic range of the Highlands and Ramapo mountain are more lightly wooded, and the timber has been more severely cut during the last twenty years than on the Central Highlands plateau westward. The proportion of forested area to the whole is about the same. In this part of the Highlands it is thought generally that the timber grows as vigorously as in former years, and it is asserted that a thirty-years' growth will yield as much wood per acre as the original forest. Some of the best timber here is on the slopes, but on the other hand more slopes have thin soil and there are more bare rock ledges than on the central plateau, and these have only a stunted growth or none, although they do not exceed probably one-third of the entire slope area. Flat hill-tops and ravines are well timbered as a rule, although some ridges are quite bare of soil on the top, and the forest is correspondingly poor.

The larger trees noted were two hemlocks, one mile southwest of West Milford, which measured thirty and thirty-six inches in diameter and about sixty feet high; a red oak at the same place measured forty-two inches by forty feet; an oak one mile north measured fifty-four inches by seventy feet, and another, one and one-quarter miles north, forty-two inches by forty-five feet, being a very beautiful tree. Near the same place we observed two chestnuts forty-two inches in diameter and forty and sixty feet high; a maple forty-two

inches by eighty feet; another, in a swamp, forty-eight inches by seventy feet; an elm thirty inches by seventy-five feet, with a beautiful spread of weeping branches. A chestnut near by measured thirty-six inches by fifty feet, and one at Midvale fifty-four inches by fifty feet; a pine at Wanaque measured thirty inches by fifty feet. No very large trees were observed on the high part of the Passaic range.

Not much reliable data could be had as to values. In the vicinity of Greenwood lake estimates ranged about as follows: Stump land, $5; twenty-years' growth, $20; thirty-years' growth, $30. At Midvale, stump land, $5; twenty-years' growth, $10 to $20; thirty-years' growth, $15 to $25; large oak and chestnut, $60 to $80 per acre.

We have noticed that a large amount of Highland forest ranges from thirty to forty years old, and only a very small amount exceeds forty-five years. All recent cutting also seems to have been of timber about thirty years old or younger. It would appear that much of the forest now standing, or which has been cut in recent years, dates from about 1850. Up to about that date there was a very large consumption of timber for charcoal to supply forges and furnaces, as well as for other kinds of fuel. Recently the cutting of timber less than twenty years old appears to have been somewhat checked. Most of this young timber was cut for charcoal, fuel and hoop-poles. The reason for this check is mainly to be found in the lessened demand or lower prices for these products. The evidence which we have collected seems to indicate that the best results are obtained by cutting at an age of thirty or thirty-five years. Chestnut particularly does not grow so thriftily after this age. A potent factor in checking this cutting of young timber is the tendency now prevailing to acquire large holdings of these northern Highlands. This movement is rapidly under way, and will undoubtedly result in a marked improvement in the condition of the forests during the next twenty years. At Wawayanda lake one owner holds 3,000 acres, and on Bearfort mountain an iron company holds 2,000 acres. At Cedar lake a club holds a large tract as a game preserve. At Ringwood, the property of Cooper & Hewitt embraces a large extent of territory. At Stickle pond a private owner has acquired an extensive preserve. Thus private enterprise seems to promise the solution of the forest question in this portion of the State. As most of this land is entirely unfit for cultivation, and should always remain in forest in order to maintain the steady flow of

the streams, as well as for other economic reasons, not to speak of the æsthetic, it is a matter for congratulation that such a movement has set in.

Over the Highland area above described, which includes about 80,000 acres of forest lands, the entire saw-mill product noted is about 574,000 feet board measure of lumber annually. In addition to this, an excelsior mill at Butler uses about 1,800 cords. There is a large consumption of railroad ties and telephone poles, and also cordwood, besides the fuel used within the district.

FOREST MAP.

The forest map accompanying this report is based on the results of the topographical surveys which indicated the forest areas as they existed from about 1885 to 1887. As we have remarked, the areas thus shown included all conditions of growth, from brush land to heavy timber. The forest areas still bear the same ratio to the entire area of upland that they did at the time of these surveys. The map, therefore, shows the percentage of area at present in forest over every part of the State. A line drawn from Long Branch across the State to Salem divides the forests pretty accurately into two kinds. Those north are nearly all, or all, deciduous, while those south are mostly, or all, coniferous. This map gives a good idea of the position of the forests and of the deforested sections. The areas left white on the map containing less than 10 per cent. of forest may be considered to be deforested, and anything less than 20 per cent. of forest indicates a pretty high state of cultivation. These areas, however, are much relieved by the usual plentiful supply of large trees standing singly or in rows along fence lines, in ravines, &c., or about residences, and by fruit orchards. Excepting, perhaps, portions of Somerset and Hunterdon counties, these trees are always sufficiently numerous to give the country a well-timbered appearance, and their value is sufficiently appreciated to make their increase more probable than their decrease in the future.

The following table is compiled from the areas given in the "Physical Description," and shows the total acreage of forest, with the percentage of upland in forest for each county and for the entire State. This does not include scattered clumps of trees of less than about ten acres in extent:

Counties.	Forest, acres.	Percentage of upland in forest.	Remarks.
Atlantic	271,638	88	Mostly coniferous.
Bergen	56,625	39	" deciduous.
Burlington	321,697	60	" coniferous.
Camden	66,588	48	" "
Cape May	75,372	72	Mixed.
Cumberland	172,978	63	"
Essex	24,239	32	Mostly deciduous.
Gloucester	126,319	37	" coniferous.
Hudson	713	05	" deciduous.
Hunterdon	39,481	14	" "
Mercer	15,829	11	" "
Middlesex	60,164	31	Mixed.
Monmouth	89,711	29	"
Morris	140,101	46	Mostly deciduous.
Ocean	295,167	87	" coniferous.
Passaic	76,170	60	" deciduous.
Salem	50,057	27	Mixed.
Somerset	28,613	15	Mostly deciduous.
Sussex	136,538	41	" "
Union	14,350	23	" "
Warren	60,205	26	" "
The State	2,069,819	46	

A PRELIMINARY REPORT ON THE FOREST CONDITIONS OF SOUTH JERSEY.

BY JOHN GIFFORD.

INTRODUCTION.

Forestry work in South Jersey began the first of July, 1894. During the five months of field work up to January, 1895, the forest conditions of the Southern Interior, which comprises all of Atlantic and Ocean and large parts of Burlington, Cape May and Cumberland counties, have been studied. The causes, effects and prevention of forest fires and the effects of drifting sand along our coast have been noted. Savanna lands have been located and examined, and experiments are in operation by which we hope to show the influence of forests on our local climate. The peculiar territory known as the "Plains" has been studied and mapped. As the forest conditions have not been studied throughout the year, this report is necessarily only preliminary, and further investigations may necessitate modifications of the views herein expressed. Every effort has been made to arouse interest in forestry, looking to the revival of the lumber industry and the establishment of other industries dependent upon forest products.

A line drawn from Sandy Hook to Bordentown conveniently separates the State into North and South Jersey. Another line from Long Branch to Salem approximately divides South Jersey into two natural geographical regions—one comprising the marl belt and alluvial lands along the Delaware, the other the Southern Interior salt marshes and beaches.

In the marl region forests are few, since the soil is devoted to agriculture. Here and there are protected wood-lots. A few acres of trees in a spot where the soil is poorest is a valuable addition to any farm. It not only improves the soil, retains the moisture and furnishes fuel, lumber and other minor products, but it lessens in many

ways the destructive forces of nature. In that way forests become evenly distributed in well-cared-for patches over all the country, and are fully as effective as broad stretches of neglected woods.

The territory known as the Southern Interior is the main subject of this report. The fertile farm land of the marl belt abruptly ends and a wooded, sparsely-inhabited region with peculiar physical conditions begins. The nature of the forests of at least a part of the Southern Interior concerns the farmers of the marl region because many of the streams which flow by their farms to the Delaware rise in its bogs and swamps. The Southern Interior is bounded on the northwest by the farm lands of the marl region, on the southwest by Delaware bay, and on the southeast by the ocean. It is included between latitudes 40° 20′ and 38° 55′ and longitudes 74° and 75° 30′. It is fringed on the bay and ocean sides by salt marshes, which are separated from the ocean by a line of slender sandy beaches. It is rolling in nature, seldom exceeding an altitude of 200 feet. Its height is greatest in a line the general course of which is nearly parallel to its northwestern border. This includes the water-sheds of South Jersey, a map of which is shown in the report of the State Geologist for 1893, page 273, illustrating the work on "Water-Supply and Water-Power," by C. C. Vermeule. Save for tongues of high land between the rivers, the region slopes gently from the water-shed to the bay and ocean, into which its largest streams flow. The region on the eastern side of the water-shed is drained by the Mullica, Great Egg Harbor, Maurice, Tuckahoe, Toms, Forked and Wading rivers, and by many creeks. Owing to the warmth of the soil, the nearness to large bodies of water, and the presence of a large amount of swamp land, the climate here is somewhat milder than that of regions in the same latitude near by. Light sandy soils predominate. There are many beds of clay, ridges of gravel and extensive areas of sandy and clayey loams. The gravelly soils are usually on the upland; the sandy, intermediate; and the loams in the lowlands. The lack of forest cover would probably tend to increase this condition of affairs, since, owing to erosion, the lightest particles are carried the longest distance. Fertile silt is thus washed into the lowlands and obstinate pebbly soils remain on the ridges. A forest cover is acknowledged to be a potent geological agent in arresting this action. The mat of roots and mulch retards the flow, the shade and windbreak prevent evaporation, and a large amount of water

instead of flowing directly to the sea is retained, absorbed by roots and transpired by leaves. There is no disintegrating rock, and owing to the nature of the formation there is probably a lack of soluble inorganic substances in the soil. It is the opinion of the majority of foresters, however, that more depends upon the mechanical than upon the chemical nature of the soil. Upon the size of the interstices of the soil depends the flow of water, and upon the quantity of water in the soil mainly depends the nature of the forest which covers it. On the other hand, rock is in the process of formation. Sand and gravel are being cemented by compounds of iron into sandstones and conglomerates. The climate, nature of the soil and the formation of rock have much to do with the peculiar forest conditions of the Southern Interior. The climate and a large percentage of the soil of this region are favorable to forest growth. A light moist soil with no hardpan near the surface is better adapted to sylviculture than to any other branch of agriculture. In this connection, Mr. B. E. Fernow, Chief of the Forestry Division of the Department of Agriculture, says: "As regards adaptability to soil, we need consider only the physical conditions of the soil, for forest trees require such small amounts of mineral matter that it is questionable whether a soil could be found that does not contain in sufficiency those that seem necessary." Light sandy soils require a forest cover to prevent shifting, to retard the flow of water and to improve their condition, since a forest exerts a recuperative and not an exhaustive influence. With the annual mulch inorganic substances from the deeper soils are deposited in litter on the surface. The forest cover, including the underbrush and herbage, prevents the pelting rains from leaching the surface soil.

The climate of South Jersey is favorable to tree-growth. Of course, the effects of cold increase as the mercury descends, but the effect of a difference of a single degree at or near the zero point means more to tree-growth than is ordinarily supposed. The effects of frost on the trunks of trees are common. Trees grow with remarkable rapidity in parts of the Southern Interior. The white oak (*Quercus alba*), which is usually associated with rich, heavy soils, grows well in Jersey sand. Clumps of virgin forest here and there and records of early travelers show that the forest-growth was once magnificent. Ship-building was for many years an important industry. Timbers hewn from Jersey pine are famous for their durability. In several

instances they have outlasted the finest varieties of Southern pine. Several schooners were timbered with Jersey heart-pine in 1861 whose frames are still sound. Enormous quantities of charcoal were used in the manufacture of iron from bog ore. Cordwood is still extensively burnt by local glass factories and brickyards, and many cords are still carried by small schooners to neighboring cities. The principal, and not the increment, has been cut and burnt, and in spite of a low price, were fires less destructive, the system of cutting judicious and the taxation in proportion to the profit, the growing of wood and other products of the forest would pay. In fact, up to recent years, the leading industries depended upon the woods.

Except for strips of cleared land along the shore and along railroads and navigable rivers, the Southern Interior is still a wooded country, only a small percentage of which, however, is worthy the name of "forest." In Ocean and Burlington counties there is an area of about 225 square miles which seems hopeless for the profitable cultivation of trees by individuals. It includes, however, an important part of the water-shed of South Jersey, and feeds hundreds of branches which flow in all directions. Other land which at one time supported a heavy forest-growth, because of reckless cutting and shameful burning with no attempt at regeneration, has gradually deteriorated. Vast areas are at present worthless and their owners "land poor." Woodland often sells for the value of the wood that covers it. Although considerable land has recently been cleared, hundreds of old fields are overgrown with pines and red cedars, and meadows once banked and cultivated are now neglected.

In the agricultural parts of South Jersey, especially along the Delaware, the planting of wood lots and belts of forests needs to be encouraged. During the strong winds of the spring clouds of sand, in the cultivated regions along the Delaware, may be seen from the Pennsylvania side, fully five miles distant. Not only do the grains of sand cut and bury crops, but the wind has a peculiar parching effect. Experiment has shown that the protection afforded by such small objects as fences is remarkable. The writer believes that next to yielding fuel, lumber and other valuable products, the most useful function of the forest is in breaking the force of the wind. The forest is a protective blanket over the face of the earth, breaking the blasts of winter, shielding the surface from the direct rays of the sun and the pelting force of rain.

In the Southern Interior of New Jersey, much of which will, no doubt, remain in forest for many years to come, in spite of its nearness to large population centers, the prevention of fires demands attention. In speaking of this region, Mr. B. E. Fernow, of the Forestry Division, says: "When the danger of loss by fire has been reduced, then it will be time to show how by the judicious use of the axe the condition and usefulness of the natural woods may be increased and finally a rational system of forest management introduced, for forestry is not what its first advocates in this country believed it to be, the preventing of the use of the forest or the relegation of the same to one use only, namely, as a cover to preserve equable water conditions. Forestry is exactly the same as agriculture. It is the application of superior knowledge and skill to produce wood crops, managing them in such a way that the largest amount of the best timber is produced in the shortest time; or, in other words, the largest income from the forest property, without leaving out of consideration the other benefits accruing from a dense forest cover."

LIST OF TREES GROWING IN THE SOUTHERN INTERIOR OF NEW JERSEY.

Important trees are marked with a star. Exotic species are printed in small capitals.

* Magnolia glauca, L. Magnolia, sweet bay, laurel magnolia, brewster.

* Liriodendron tulipifera, L. Tulip tree, white poplar, whitewood, yellow poplar, magnolia maple.

Xanthoxylum Americanum, Mill. Prickly ash, toothache tree.

AILANTHUS GLANDULOSUS, Desf. Tree of Heaven, tallow tree, pride of China, stink tree.

* Ilex opaca, Ait. American holly.

* Acer rubrum, L. Red maple, swamp maple.

ROBINIA PSEUDACACIA, L. Common locust.

ROBINIA VISCOSA, Vent. Clammy locust.

GLEDITSCHIA TRIACANTHOS, L. Honey locust.

Prunus Americana, Marsh. Wild, yellow or red plum.

Prunus serotina, Ehrh. Wild black cherry.

PYRUS MALUS, L. Apple.

* Liquidambar styraciflua, L. Bilsted, sweet gum, ling, alligator wood.

Cornus florida, L. Dogwood.

* Nyssa sylvatica, Marsh. (*N. multiflora*, Wang.) Sour gum, tupelo, pepperidge, black gum.

Diospyros Virginiana, L. Date plum, persimmon.

Fraxinus Americana, L. White ash.

Fraxinus viridis, Michx. f. Green ash.

Chionanthus Virginica, L. Fringe tree.

Catalpa bignonioides, Walt. Indian bean, catalpa.

*Sassafras officinale, Nees. Sassafras.
Ulmus Americana, L. Common elm.
Celtis occidentalis, L. Hackberry, sugarberry, bastard elm, juniper.
Morus rubra, L. Red mulberry.
MORUS ALBA, L. White mulberry.
Platanus occidentalis, L. Plane tree, buttonwood, sycamore.
Hicoria ovata (Mill.), Britt. (*Carya alba*, Nutt.) Shagbark, shellbark.
*Hicoria alba (L.), Britt. (*Carya tomentosa*, Nutt.) Mokernut.
Hicoria glabra (Mill.), Britt. (*Carya porcina*, Nutt.) Pignut.
Hicoria minima (Marsh.), Britt. (*Carya amara*, Nutt.) Bitternut.
Juglans nigra, L. Black walnut.
*Betula populifolia, Marsh. White birch.
*Betula nigra, L. River birch, red birch.
Quercus alba, L. White oak.
*Quercus minor (Marsh.), Sargent. (*Q. obtusiloba*, Michx.) Post oak.
*Quercus bicolor, Willd. Swamp white oak.
*Quercus prinus, L. (*Inchides, var. monticola*, Michx.) Chestnut oak.
Quercus Muhlenbergii, Engelm. (*Q. prinus*, L., *var. Acuminata*, Michx.) Chestnut oak.
*Quercus Muhlenbergii, *var.* humilis (Marsh.), Britt. (*Q. prinoides*, Willd.) Chinquapin oak, sweet acorn.
*Quercus phellos, L. Willow oak, pin oak, peach-leaved oak.
Quercus phellos, *var.* pumila, Pursh.
*Quercus nigra, L. Black-jack.
Quercus heterophylla, Michx. f. Bartram's oak.
*Quercus ilicifolia, Wang. Scrub oak.
*Quercus cuneata, Wang. (*Q. falcata*, Michx.) Spanish oak.
*Quercus coccinea, Wang. Scarlet oak.
*Quercus tinctoria, Bartr. Black oak.
*Quercus rubra, L. Red oak.
Quercus palustris, Du Roi.
*Castanea sativa, Mill., *var.* Americana (Michx.), Sargent. Chestnut.
*Fagus ferruginea, Ait. Beech.
Salix humilis, Muhl. Low willow.
*Salix discolor, Muhl. Common swamp willow.
Salix sericea, Marsh. Silky willow.
Salix cordata, Muhl.
*Salix nigra, Marsh. Black willow.
SALIX ALBA, L. White willow.
Populus tremuloides, Michx. Aspen.
POPULUS FASTIGIATA. Lombardy poplar.
Populus grandidentata, Michx. Large-toothed aspen.
POPULUS ALBA, L. White poplar, abele.
*Chamæcyparis thyoides (L.), B. S. P. (*Cupressus thyoides*, L.) White cedar.
*Juniperus Virginiana, L. Red cedar, savin.
*Pinus rigida, Mill. Pitch pine, rough-bark pine.
*Pinus Virginiana, Mill. (*P. inops*, Ait.) Scrub pine, spruce pine, hemlock pine.
*Pinus echinata, Mill. (*P. mitis*, Michx.) Yellow pine, smooth-bark pine.
*Pinus strobus, L. White pine.
Tsuga Canadensis (L.), Carr. (*Abies Canadensis*, Michx.) Hemlock spruce.

GEOGRAPHICAL DISTRIBUTION OF TREES IN THE SOUTHERN INTERIOR OF NEW JERSEY.

Owing to the physical conditions of the Southern Interior the sylva is peculiar. The geographical distribution of trees is dependent upon a great variety of conditions. There are agents of dissemination and barriers of much and little importance. The species that can overcome these hindrances with the least difficulty predominate. In order to explain, therefore, the distribution of trees in South Jersey a knowledge of the barriers, of the ability of the trees to overcome these barriers, and of the agents of dissemination is necessary. All this embraced under the general phrase of "forest conditions," is necessary in order to devise a rational local system of forest regulation.

Trees are usually distributed by winds and currents of water, and by animals and man. Fruits are usully supplied with attachments in the form of wings or with bright colors and sweet juices to aid in their dissemination. The principal barriers are unsuitable climatic, soil, and moisture conditions, ravages of fire, animals, especially insects and cattle, parasitic plants, mainly fungi, man, and the contention with other plants which have gained, or are striving to gain, possession of the soil. On the upland of the Southern Interior the distribution of trees is mainly the result of years of careless cutting and burning. The original forest cover has practically disappeared and a large percentage of what remains is in a poor condition. The choicest timber on the upland was yellow pine (*Pinus echinata*). Only several small patches of this virgin pine remain, the finest of which is at Inskipps, on the road to the Blue Hole from Winslow. Another beautiful grove may be seen at Jenkins Neck, and other clumps have been left in protected spots. It is known to woodmen as the smooth-bark pine.

The rough-bark or pitch pine (*Pinus rigida*) not long ago was the dominating forest tree. The adaptability of the species is remarkable. It is common on the driest uplands, where other trees perish, but grows much larger in a shorter time in the deepest swamps. The growth of this pine illustrates a point which explains the distribution of trees in many places. A species grows where it meets with the least opposition. It is not preference, but endurance. The red cedar (*Juniperus Virginiana*), for instance, in South Jersey, grows in dry

fields, while in the Southern States it is common in swamps. The quality of the timber also depends upon the location of the tree. Upland pitch pine is full of resin and is fit only for rough work and cordwood. Swamp pitch pine is lighter, more durable, and is in demand for planks and logs. It is claimed that the red cedar which grows on the beaches of South Jersey is much more durable than that which grows on the mainland.

It is a fact worthy of notice in this connection that the white pine (*Pinus strobus*) is usually associated with rather rocky uplands. The only place in South Jersey, in the knowledge of the writer, where it grows in the forest is in Manahawkin swamp. It has been much cut, but a number of large trees remain. They overtop the cedars and other trees of the swamp and have grown with remarkable rapidity. Stumps twenty-five inches in diameter average about fifty annual rings.

The spruce pine (*Pinus Virginiana*) is abundant in West Jersey, on gravelly ridges. Small clumps and single trees are scattered sparingly through the Southern Interior.

According to the leading botanists, the habitats of the pines which grow in South Jersey are as follows: *Pinus Virginiana*, "dry, sandy or gravelly ridges;" *Pinus echinata*, "sandy or light clayey soil;" *Pinus rigida*, "sandy, barren soil;" and *Pinus strobus*, "rocky upland." In South Jersey *Pinus rigida* and *Pinus strobus* grow the best in deep swamps; *Pinus echinata* in light, loamy soil, and *Pinus Virginiana* on gravelly ridges.

The pitch pine is disappearing. It is a common observation that oak follows pine. This is the result of cutting and burning with no attention to regeneration. Shoots spring up from the collar of the stump of a burnt or cut pine. These come from dormant buds, and when a few inches high they wither and die. The smaller the stump, however, the more vigorous the shoots. There is practically no second growth to Jersey pine. A pine stump is soon invaded by several kinds of insects which eat the inner bark and outer wood. Even eggs are deposited in the soft young shoots. The bark of the stump thickens in places, pitch exudes and the scions die. Finally, the stump is devoured so that a shell of bark alone remains. Oak, on the other hand, produces a vigorous second growth. In almost every pine woods there are a few oaks. The ground is often seeded by squirrels and other animals. When the pines are cut, these sup-

pressed oaks, with increased sunshine and no opposition, grow rapidly. Oak, with its vigorous second growth, supplants the pine in places where the soil and moisture conditions are suitable. The majority of plants when asexually reproduced degenerate in the course of time. The oak has much vitality in this respect, but an oak from the stump is inferior to an oak from the seed. The light-winged pine seeds, though freely scattered by the wind, are easily burnt by passing fires and the second growth soon withers and dies, so that the days of our pines are numbered unless cared for by the forester.

The question of regeneration, next to that of fires, is the one which needs attention throughout the whole of South Jersey. It is the work of the forester to protect the weakest, if a valuable species. Weak valuable trees are often overwhelmed by hardy worthless kinds. The white cedar, for instance, is often replaced by swamp maple, magnolia, sour gum and the like.

The oaks which have followed the pines are striving for a foothold against fire and careless cutting. The weaker species will perish. Scrub oaks and bushes will soon alone remain, and finally even these will die, and a shady wood, inhabited by a great variety of creatures, will become a lifeless desert. It is not necessary to imagine this. Such, in fact, is the condition of a large area in Burlington and Ocean counties. Owing to fires the pines are black and dead, the ground is white and bare and living things are remarkably scarce.

If fires are stopped, natural recuperation begins, and in the course of years by slow stages forest conditions are established. It begins with lichens, grasses and low heaths. Seeds of pioneer trees, such as the conifers, are accidentally carried. It is, nevertheless, a matter of chance. By aiding nature in overcoming these barriers reforestation can be hastened. The soil of the Southern Interior recuperates slowly.

Fields in South Jersey when abandoned soon become covered with Indian grass, the light seeds of which are sown by the wind. If a pine woods is near, many young pines appear, with here and there a red cedar, the seeds of which are disseminated by birds which feed upon its fruit. The red cedar is usually scattered along fences, and owing to the density of its evergreen foliage breaks the force of the wind and shields the field.

The difference in the rate of growth between pines which come up in an abandoned field and in a region which has been burnt over is very noticeable.

Now and then in the woods, usually among the oaks, a hickory may be seen.

The chestnut grows well in the Southern Interior, but is scarce, owing to fires. It still grows wild, as at "Chestnut" neck, where it was once abundant.

There is little oak of value left on the upland. In or near villages in protected localities large specimens may still be seen. Jersey upland oak has been cut many times, although still called "second growth." It is now mainly used for cordwood. Post oak (*Quercus minor*), black oak (*Quercus tinctoria*), white oak (*Quercus alba*), chestnut oak (*Quercus prinus*), Spanish oak (*Quercus cuneata*), red oak (*Quercus rubra*), black-jack (*Quercus nigra*) and scarlet oak (*Quercus coccinea*) are all used for fuel. The scrub oak (*Quercus ilicifolia*) is common, but is of little use. The upland oak, owing to fires and continual cutting, has degenerated. Hybrids and irregular forms are common.

Although frequent along streets and around dwellings, one seldom finds the buttonwood (*Platanus occidentalis*) in the woods. This is probably the largest tree that grows in the Eastern United States. It is claimed by many that they sometimes rival in size the giants of California and Australia. There are several beautiful specimens in the cultivated regions of New Jersey.

There are few elm and ash trees in South Jersey. The catalpa, lindens, ailanthus, poplars, locusts, maples (excepting the swamp maple) and mulberrys have been planted, but have not gained a foothold in the forest.

The haphazard introduction of foreign trees is attended with danger. It is difficult to predict the effect of bringing an exotic tree into a new environment. We can recommend the following trees for planting: White cedar (*Chamæcyparis thyoides*), yellow pine (*Pinus echinata*), white pine (*Pinus strobus*), chestnut (*Castanea sativa, var. Americana*), white oak (*Quercus alba*) and swamp white oak (*Quercus bicolor*). There are no doubt many trees and shrubs growing in the South which would thrive in South Jersey.

The wild cherry (*Prunus serotina*) is common in fields, the seeds of which have been carried by birds. This tree is in ill-repute with farmers because, it is claimed, it exhausts an undue amount of the soil. Crops in the region of a wild cherry tree are very noticeably affected.

The red cedar (*Juniperus Virginiana*) seldom grows in the woods of the Southern Interior but is common in the fields. The presence of these trees in fallow fields is usually attributed to the fact that they can endure dry, sandy soils better than other species. It is mainly a matter of chance, however, whether the pines or cedars get disseminated first. One is dependent upon the winds, the other upon birds. This tree is very seriously affected in South Jersey by a peculiar fungus (*Gymnosporangium macropus*), commonly called "cedar apples." This heterœcious parasite summers on the leaves of the apple. The cedars on the beaches are slightly, if at all, affected by this fungus.

The Lombardy poplar (*Populus fastigiata*), a native of Asia, once so common around old dwellings, is rapidly losing its hold, owing, it is claimed, to the fact that only trees of one sex were introduced into this country, the male and female flowers being on separate trees. This is an interesting example of the effects of long-continued asexual reproduction.

The common locust (*Robinia pseudacacia*), a native of our Southwest, is a tree which yields a very valuable wood and grows under adverse conditions, but is much affected by the ravages of a borer which causes the limbs to die, so that the tree presents a very straggly appearance.

The ailanthus (*Ailanthus glandulosus*), a native of Asia, was once much planted along streets and in barren soils, but is generally disliked on account of the disagreeable odor of its flowers. The male and female flowers are on separate trees, and this objection can therefore be avoided by planting only the female tree, the flowers of which are odorless. The wood is more valuable than is usually supposed.

THE PLAINS.

In Burlington and Ocean counties there are two remarkable areas known as the East and West Plains.* The "trees" which grow there seldom exceed four or five feet in height. The growth is usually much shorter. A large percentage of the territory is covered with bushes about a foot high. In places the surface is almost bare. Low pitch pines (*Pinus rigida*), scrub oaks, and black-jack, laurel (*Kalmia latifolia*) uva-ursi (*Arctostaphylos uva-ursi*), arbutus (*Epigæa repens*), and other heaths grow there. Even the pyxie (*Pyxidanthera barbulata*), which is usually found in damp lowlands, is not uncommon.

*See Plate XI. for location.

In the sloughs grasses, several kinds of bushes, swamp maples and white cedars grow. On the East Plains a sassafras is the highest tree. It is about fifteen feet high. The pitch pine is most abundant. It is mainly a weak, degenerated second growth. The stumps just under the ground are much bunched and full of resin; above ground they are often knobbed by insects. They are called "she-pines" by the natives and bear a large number of prickly cones.

The laurel (*Kalmia latifolia*) is the most vigorous plant on the plains. It is a beautiful evergreen shrub growing higher than the surrounding pines. It often reaches the dimensions of a tree in our swamps but is of remarkably slow growth. It is a valuable underbrush owing to its ability to endure to a remarkable extent fire, dryness and other adverse conditions, although it thrives in swampy regions.

The East Plains are located just southwest of Cedar Grove. They contain 6,662 acres. The West Plains are just northwest of Cedar Grove and contain 7,737 acres. They are separated by the east branch of Wading river. They are almost wholly in Burlington county and are almost north and south instead of *east* and *west* of each other.

The Plains are hilly, the hills varying in height from 100 to 105 feet. This territory is an important part of the water-shed of South Jersey. Many streams rise in the sloughs along their edges. In several places the borders of the plains are sharply marked, but mostly they grade indistinctly into the surrounding territory.

A farmer on the edge of what are called the Little Plains, which are really a part of the West Plains, has cleared a patch for cultivation and seems confident that crops will grow there in its present condition. It is likely that more berries and sweet potatoes can be produced than timber trees. It is often the case that land unfit for other crops will grow trees, and often land unfit for trees will grow other crops. The same farmer, however, dug several maples from the swamp and planted them on the Little Plains. They grew until killed by fires. The white cedar which lines the small branches that run into the Plains looks fresh and thrifty. At Cedar Grove, in the valley between these Plains, trees grow without difficulty and the soil is productive.

On the Plains the surface-soil is white sand, the subsoil a clayey loam and gravel at varying depths, generally within one or two feet.

of the surface. The subsoil is quite hard, rendering the penetration by roots difficult. In many places a hardpan of iron ore has formed, or is forming. In other places there are beds of clay.

The results of the chemical examination of the soil of the Plains are not discouraging. Owing to the absence of disintegrating rock, and leaching due to rains beating on the barren surface, a lack of soluble inorganic substances is expected. A dearth of these substances in the soil is, however, probably in itself insufficient to prevent the growth of trees.

Two specimens of the surface-soil of the Plains and two from the surrounding territory where trees of fair size are growing were analyzed. These examinations seem to indicate that the difficulty is not a chemical one. According to the following analyses the soil is certainly rich enough to support a good forest growth:

	Surface soil of Plains.		Surface soil of edge of Plains where trees are growing.	
	No. 1.	No. 2.	No. 3.	No. 4.
Nitrogen	0.06	0.03	....	....
Phosphoric acid	0.17	0.19	0.02	0.01
Potash	0.05	0.02	....	....
Lime	0.06	0.02	....	....
Silica, insol	96.40	96.95	97.60	97.28
Alumina	1.15	0.28	....	....
Ferric oxide	0.40	0.20	....	....
Ferrous oxide	1.26	1.06	....	....
Magnesia	0.04	0.02	....	....

Trees which are not second growth on the Plains seem to reach a certain size and then die. The tops perish first, presenting an appearance which is often called "stag-headed" or "top-dry." This is a condition which is usually due to a lack of water, or, owing to the nature of the soil, the roots are unable to perform their proper functions.

The Plains have been burnt over many times. Being considered worthless, fires have had their way. There are stumps and now and then dead trunks of trees of larger size than those growing there to-day. Much of the pine is at present about twelve years old.

This peculiar territory is probably caused by a combination of barriers. Destructive fires must be ranked first. These have burnt the seeds, produced a worthless second growth, destroyed surface mulch, exposed the soil to the beating force of the rain and the dry-

ing effect of the winds. Next comes an obstinate subsoil, which prevents the penetration of roots, and finally a lack of moisture, due to a lack of forest cover and to the hilliness of the country.

It is impossible to tell whether the Plains have ever supported a forest growth of considerable size. It is the testimony of tradition that trees have never grown there. The belief is also paramount that trees will not grow there. Owing to fires, there are regions in all grades of condition, some of which in Ocean county are already in as bad a state as the Plains.

The Forked river mountain region is little, if any, better than the Plains. Perhaps the Plains once supported a growth similar to that which may now be seen on high, gravelly ridges where no fires have burnt. It is likely, also, that by stopping fires and reseeding to a certain extent with a species which can endure adverse conditions a growth can be produced in the course of time which, even if unsuccessful in the production of merchantable timber, will have a beneficial influence in regulating the supply of water in the streams which rise in the sloughs along their edges.

These wind-swept, sun-scorched Plains, and the contiguous territory, embracing the heads of streams which flow into both the Delaware and the ocean, are well fitted for a reservation. They are, at present, useless except to land speculators and pine-knot gatherers. Their proper improvement is beyond the power of individuals. As an object lesson and a benefit to the surrounding territory, especially to the bogs, which demand a regular flow of water, no better spot for a reservation could be selected in the Southern Interior of New Jersey.

The reforestation of such areas is a slow and difficult process. Considerable experimentation is necessary before conclusions are warranted. The first and most important questions are what and how to plant. The first step is, of course, to stop fires, which is a simple matter in such a region, owing to the meagerness of the growth, so that a good undergrowth can establish itself. Economic shrubs, such as the laurel and sumac, grow well on the Plains. Several leguminous plants have been recommended, owing to the rapid way in which they enrich the soil. In the lowlands, where there is no hardpan, willows and white cedars will grow. Conifers are most suitable for planting on dry uplands for at least two reasons—first, they furnish a dense cover throughout the year, and, second, they can endure with from one-sixth to one-tenth the amount of water required by deciduous trees.

SWAMP LAND.

A very large amount of the Southern Interior of New Jersey is swamp land, semi-swamp land, savanna-land and cripple. Low, grassy areas are called "savannas," and low, bushy areas "cripples."

The most important tree in the lowlands is the white cedar (*Chamæcyparis thyoides*). From the accumulation of cedar logs in the beds of many swamps it is safe to call it a native tree. There is nothing more characteristic of the region than swamps of cedar. It grows in dense masses along fresh-water streams. It is becoming scarce owing to the value of the lumber, lack of attention to regeneration and demand for the bottom for cranberry bogs.

When a cedar swamp is cut, the kind of trees which follows depends upon several conditions. If the ground is seeded with gum, maple and the like, the cedar loses its hold. If the bottom is not well seeded with other trees and the surrounding cedar is in fruit it may come up in cedar. It must be borne in mind also that the year, as well as the time of year, has its influence, since to trees there are vegetative and reproductive periods. The cedar is usually a prolific seed-bearer. Its small, winged seeds are disseminated by the wind. It fruits when very young. It is not uncommon to find a white cedar three feet high in fruit.

When a swamp bottom is burnt it often comes up in white cedar as even and dense as a field of wheat, while a swamp which has been cut and not burnt over produces a great variety of swamp trees. Although a common observation, this is more or less of accidental occurrence. A swamp bottom is usually well seeded with a variety of trees and shrubs, the seeds of which have been carried there in a variety of ways. A fire destroys these seeds and forms a soil on the surface of the muck. If this occurs when the cedar is in fruit, its light seeds are sown by the wind and cedar soon abundantly appears.

There are thousands of acres of land in South Jersey where the cedar will grow with little care, but owing to brush and other less valuable trees it is unable to establish itself. There is a small but thrifty swamp in Atlantic county which originated in this way: Three cedars were planted in a meadow. Other trees were not allowed to grow. Soon the ground was seeded and a mass of young cedar appeared. The trees are now fit for timber and the three originals may

plainly be seen above the rest of the swamp. After the stopping of fires the regeneration of white cedar deserves attention.

In many low regions white birch is coming in large quantities. It never grows to a very large size in South Jersey. It is used to some extent for umbrella handles and canes. The river birch is also not uncommon.

Willows are not plentiful in South Jersey although there is much land adapted to their cultivation. They are mainly disseminated by the wind. The branches which are snapped off by winds and rushing water easily take root in swampy places.

The hardwood swamps usually contain maples (*Acer rubrum*), bilsted (*Liquidambar styraciflua*), tupelo (*Nyssa sylvatica*), and brewster (*Magnolia glauca*), with swamp huckleberry, swamp sumac and other bushes. In several localities there are swamps characterized by a great variety of species. In Griscom's swamp, between the Tuckahoe and Great Egg Harbor rivers, large beeches and tulip trees are growing, also swamp white oak (*Quercus bicolor*), white oak, black oak, chestnut oak, willow oak (*Quercus phellos*), bilsted, brewster, birch, holly, sassafras, tupelo, swamp maple, pitch pine and white cedar. Willow oak and bilsted are plentiful in Cape May and Atlantic counties. This swamp is the only place in South Jersey known to the writer where the swamp-white-oak is abundant. It is a magnificent tree and deserves to be planted in low regions. Manahawkin swamp resembles Griscom's in the variety of its trees. It contains, however, a large amount of white cedar, also white pine, which has not grown in Griscom's.

These are good examples of the condition of the original swamps of New Jersey. They have not been seriously affected by fire. It is remarkable, however, to find beech and tulip trees on the ocean side of New Jersey separated from the beech-and-tulip-tree country by a broad stretch of pine land. The writer believes that the chestnut, beech, tulip and other trees were once well distributed throughout the region, but owing to their inability to stand fire and owing to the demand for certain kinds of timber, the species able to endure fire the longest and the useless species have increased accordingly. The selection of the best from the forest, even if the trees which are cut are of a large size, will cause it to deteriorate in the course of time if no attention is paid to the young trees which follow.

SAVANNA-LAND.

There are many acres of savanna-land in South Jersey. The true savanna consists of sloughs covered with a variety of grasses, with knolls or ridges where scragged pitch pines grow. These sloughs are underlain near the surface by a layer of bog-iron ore. On the knolls the soil is deeper, so that trees can gain a footing. In many cases the tap-root of the pine has been unable to penetrate the soil to support the tree and this topples over in consequence. The reforestation of such a territory seems almost hopeless. Willows however would probably grow there.

The presence of iron in solution is not detrimental to tree growth, in fact a certain amount of iron is necessary. Experiment shows that in the absence of iron no coloring matter is formed in the leaves.

Vegetation is a potent geological agent in the formation of bog ore, which in turn is an effective barrier to the growth of trees. The insoluble red coloring matter in the soil of South Jersey is ferric oxide, which by a series of chemical changes through the agency of decomposing organic matter is washed out and deposited in bogs, where it cements sand and gravel into an obstinate hardpan.

There are three kinds of savanna-lands in South Jersey, due to as many causes. The first is the true savanna produced by a hardpan. The second embraces grassy areas due to an excess of water. They are usually fringed, where the water is less abundant, by bushes, mainly cassandra, called "prim" by the natives, and huckleberry. The formation of such places is illustrated in the preparation of cranberry bogs. The place intended for a bog is banked and flooded. In the course of a couple of years, all the vegetation except water grass is killed. Few trees can grow in an excess of water. The physiological changes in the roots demand an abundant supply of oxygen.

A kind of savanna is produced by fires in swampy regions. Trees and bushes are killed, while the condition of the grass is actually improved by fire. It has been customary for many years in some countries to burn the grass to improve its condition, thus killing or preventing the growth of trees for the sake of a few cattle. Burning, together with the ravages of cattle, is sufficient to account for vast areas of grassy land, especially where the soil is not very favorable to tree-growth. The burning of savanna-lands is still practised

to a slight extent in South Jersey. In such areas charred stumps are sufficient to indicate that a forest once grew there.

Savanna-land formed by fire and cattle, or even by an excess of water, will recover in the course of time. In places where land is scarce and labor cheap, bog ore has been broken so that trees may gain a footing. In limestone and other rocky regions the organic acids emitted by the roots of plants and decaying vegetable matter aid in the decomposition of the rock, but a territory underlain with an impervious layer of bog ore seems hopeless. The writer believes, however, that the growing of willows and the swamp huckleberry in such regions to be worthy a trial.

THE SALT MARSHES.

The salt marshes on the bay and ocean sides of the Southern Interior are of interest from a forestry standpoint because of their treelessness. Although soft and fertile, the presence of brine is an effective barrier to all our common species of trees. Here again the grasses, sedges and a few other low herbs are alone able to endure. When banked and sluiced these marshes freshen. Such a soil would be well fitted for growing the white cedar and willows.

THE BEACHES.

The distribution of trees on the beaches of South Jersey is peculiar. There the forest has not suffered seriously from the effects of fire. The soil is a fine, moist sand in which, provided other conditions are favorable, trees grow rapidly. The fact that there is a little larger rainfall, and that the climate is generally more moist and equable than in the Southern Interior, may account in part for the vigorous growth of trees along the shore. The marshes have acted also, no doubt, as a barrier in preventing the spread of seeds from the mainland by winds, since a large majority of the trees which grow there are those which are usually distributed by birds. The forest suffers from the effects of strong winds and moving sands. Inland the trees bend toward the east, owing to the prevailing west winds, but along the shore they lean toward the west, owing to strong sea-breezes during the period of growth. The principal trees are the red cedar, the holly, the tupelo, magnolia, wild cherry, hackberry, sassafras, and swamp

maple. Oaks and a few pines may also be found. Red cedar and holly are the predominating trees. Holly reaches a very large size on these beaches. In the woods on Seven-Mile beach the red mulberry is growing. On this beach the effects of drifting sand are well illustrated.

When the tide falls the sand dries on the surface and is blown inland. Dunes are formed, some of which are thirty or forty feet in height. Behind these dunes is a dense forest, semi-tropical in nature. The sand blast trims the tops of the trees near the edge of the moving dune as flat as though cut with shears. The movement of these dunes is peculiar. They are not hurled in large masses, at irregular intervals, by strong winds. The sand, ground to powder by the waves, when damp is solid and immovable, but any sunny day when a sea-breeze is blowing, dried by the sun and wind, it flies over the surface like fine drifting snow and falls over the edge of the dune, slowly but surely killing the forest before it. The trees prevent the wind from blowing back the sand. The formation and movement of these beaches along the Jersey coast and the part played by these forests in aiding or preventing that movement is a question of much interest, deserving more attention than it has yet received. Along the Biscayan shores in France, in Denmark and elsewhere, drifting sands have been stopped by sowing reeds, grasses and the like.

Many trees on these beaches have died prematurely. This is often due to sand drifting around their roots. One may dig and waves may wash a large quantity of earth from the roots of a tree and it will live, but fill in, often only a few inches, and it perishes in consequence. This has often been noticed in grading lots. The supply of air to the roots is probably thus affected.

On Five-Mile beach there are no dunes of consequence, but a dense forest and many peculiar growths. Holly there disports itself like a member of the fig family. It is not uncommon to find two hollies grown together, or a limb of one grown fast to another holly, or one limb uniting with another limb of the same tree or joining the trunk to form the so-called "jug handles." In one instance two hollies are embracing and slowly killing a red cedar, several of the dead limbs of which have been surrounded by the trunks of the hollies. Here are countless examples of tree contention. The limbs of the hollies are matted and zigzag. The trees are full of limb-holes, favorite nesting-places for flickers, which, with the robins, are potent agents

of tree distribution. The forest at one time was very dense and the underbrush a mass of green briars.

This condition is probably due to a combination of causes. Vigor and density of growth are due to a mild, moist climate and a soft, moist soil. Strong winds and the work of cattle account, no doubt, in part, for the close, jagged growths which are common there. Cattle, for many years, ran wild on these islands. The last were shot only a few years ago. Even the prickly leaves of the holly are eaten by hungry cattle, limbs of considerable size are pulled down and broken off. Trees which they do not eat are injured when young by being broken and crushed.

The part played by mankind in effecting the distribution of trees and the conditions of our forests and their environment is of course paramount. In few places is it better illustrated than in parts of South Jersey. Man is at one time an effective barrier and again a potent agent of distribution. The results of his reckless prodigality are everywhere visible. With little thought of posterity our woods have been treated in a shameful manner. Although the principal industries once depended upon the woods, regeneration of depleted areas has received but little attention. This must be overcome by the education of the coming generation in the rudiments of forestry, and efforts are now in progress in that direction by the formation of associations and the distribution of literature on the subject. Although trees have been planted and groves protected by the better element of society, fires caused by maliciousness and carelessness have done damage which will require years of patient work to repair. After years of such negligence the State owes those territories which have thus been impoverished a certain amount of protection. All that our woods need is simply common-sense treatment. It can be expressed in two short phrases—the prevention of fires and the judicious use of the axe.

CAUSES, EFFECTS AND PREVENTION OF FOREST FIRES.

Fire is the main cause of forest deterioration and of the general impoverished condition of a large part of the Southern Interior of New Jersey. There are few stretches of woodland in this region which have not been more or less damaged in that way.

The causes of forest fires may be classified as follows: Incendiaries, careless individuals, locomotives and lightning. Professor Cook, in

an article in the Fifteenth Annual Report of the State Board of Agriculture, says: "The causes of these fires are various. Those given for the fifty-four fires of the census year (1880) are as follows: Clearing land, seven; locomotives, twenty-eight; hunters, six; malice, seven; coal-pits, six." He estimated that the area burnt over during that year amounted to not less than 128,000 acres.

The most serious fires are usually those which are purposely set. An incendiary bent upon mischief waits until the wood is dry and the wind in the desired direction. There are usually two motives back of incendiarism—first, individual gain at the expense of another; second, revenge.

A few years ago it was not uncommon for colliers to fire a wood in order to buy it cheaply. The charred wood is then only fit for charcoal. Owing to the decline of the charcoal industry and the abundance of charred wood in the forests, this is not practiced at present. In speaking of this in the article above referred to, Professor Cook says: "Many fires no doubt start from coalings, and it is common to hear the belief expressed that some of these are started intentionally, in order to keep the coalers and wood-choppers at work, since timber burned over must be cut at once, whereas it would otherwise be left to grow and increase in value. Those caused through malice often are the result of punishing or holding under surveillance of timber thieves, by no means uncommon in the pine forests."

Fires were set in meadowy regions to improve the grass for cattle. Savanna-lands are still burnt for that purpose where cattle are turned into the woods.

It is claimed that berry-pickers set fire to huckleberry bushes to improve the berry crop. In a couple of years the young growth which follows bears larger and finer berries. Wood thieves, it is said, set fire to the brush and stumps to prevent detection. There are many people living in the woods of the Southern Interior who own no woodland, but who gain a livelihood in a variety of ways out of woods which belong to other people. They are mostly berry-pickers, hunters and wood-choppers.

Fires are set out of spite. If a backwoodsman thinks himself wronged by a woodland owner, he often "gets even" in a dastardly way by touching a match to his woods. It is certain that for a variety of such purposes fires are set. Such fires do much damage, and such people are difficult to convict. It is this discouraging uncertainty

which has prevented many improvements in the woods of South Jersey. Woodland-owners during forest-fire season feel insecure, expecting a fire at any moment. The fire may be set to injure an enemy, the wind may suddenly change and the result is difficult to predict. Several fires in Atlantic county were set last season in the same region several nights in succession.

Second in importance are fires set by careless individuals. In clearing land fires escape from burning brush. A large foreign element has come to South Jersey to clear farms. This increases the danger while the land is being cleared; later these cleared areas will act as fire-breaks. Tramps, hunters and boys with camp-fires, lighted gun-wads, cigars and cigarettes cause many fires.

Locomotives are also often blamed. It is certain that many fires have been set by sparks from the stack and hot coals from the grate. The majority of the roads are using some care. On some roads engineers have been cautioned, safety-strips have been cleared and in one instance furrows have been ploughed along the road, and section men usually endeavor to put out the fires when caused by the locomotives. If engineers are careful, if the spark-arrester is not withdrawn or poked with holes, if coals are dumped only in places prepared for that purpose, if safety-strips are cleared and furrows ploughed along the road, and if section men are watchful and willing, there is little danger from that source. It is certain that some railroads are using more precautions at present than woodland-owners themselves.

Although not common, fires have been set by lightning. Certain species and solitary trees are more apt to be struck than others. There are several indications that a disastrous fire was set last summer in South Jersey by lightning which struck a solitary tree in a field of dry grass.

The amount of damage depends, of course, upon the severity of the fire, which in turn depends upon the dryness of the wood, the force of the wind, the time of year, the kind of trees and the nature of the underbrush and soil. Often everything above ground is killed. The charred boles of hundreds of trees fall and rot in the woods. In low ground, after a fire, fresh green underbrush appears, but high land recovers slowly, often remaining bare for many years.

There is danger from fires about six months of the year. They are very destructive during the high winds in the spring, when there

is little sap in the wood. Dry leaves cover the ground and many cling to the low oaks.

Often large pine trees appear to be but slightly affected by a ground fire which burns the underbrush and leaves on the surface. Bark is a non-conductor of heat, but if the cambium, the active part of the tree just beneath the bark, is affected, the tree dies. Even then, if it happens in the spring, the tree appears to be recovering. Dormant buds in the trunk sprout and fresh green leaves are formed. It is better to cut such trees, since they soon die. When the starchy matter in the trunk is exhausted these sprouts wither and die, the tree is invaded by insects, rots and topples over. Even a pitch pine log, if cut in winter, sends out fresh shoots from dormant eyes in the spring. Even if the tree itself is not directly injured by fire, its supply of nutriment and moisture is affected by burning the undergrowth.

The burning of underbrush has been advocated as a sort of remedy for the prevention of fires. Some have suggested cutting down the underbrush and trimming the trees. Such work would be expensive, would do no good and in the end would be detrimental to the forest. Underbrush, in many places, is essential. It must, however, be the proper kind of underbrush. We would recommend some economical shrub. It is true that underbrush smothers young trees, but this is not a serious difficulty in properly-cared-for forests. The amount of mineral matter which a tree absorbs is insignificant. Water is the essential element. In checking evaporation and retarding the flow, undergrowth is often necessary. On the removal of natural litter and undergrowth from a young forest the trees become sickly and unable to resist the inroads of parasites. In old pine woods on upland there is often little underbrush. The ground is covered with a thin layer of pine leaves. In the finest virgin-pine forest (*Pinus echinata*) in South Jersey, where no fires have burnt and no trees have been cut for many years, there is a dense underwood, the chestnut oak predominating.

Stump-holes are common in pine woods. When a pine tree is cut or burnt the stump decays and a hole of considerable size, with many ramifications, is formed. The ground is often riddled with such holes from suppressed trees. These drain the water from the surface. This, together with the slight shade of pines and the lack of under-

brush, accounts for the dryness of the soil and atmosphere of a pine woods.

The question of underbrush in relation to the trees and soils of South Jersey needs to be carefully studied; there is every reason for believing, nevertheless, that the proper kind of undergrowth is needed in the woods of this region.

The effects of forest fires may be classified as follows: Destruction of timber and other property, extermination of valuable species, impoverishment of soil and destruction of seeds and game.

The destruction of timber, cranberry bogs, and even dwellings, although it amounts to many thousands of dollars in the course of a few years, is probably insignificant compared with the damage consequent upon this, which is beyond calculation. Were we to allow only the small sum of fifty cents damage to the acre, during the last five years the loss amounts to not less than $300,000. In referring to the damage done in New Jersey by fires in 1880, Prof. Cook says: "A large amount of cedar swamp was destroyed by these fires, and $10 per acre would not more than cover the direct damage to timber, making the loss for this year $1,280,000, nearly equal to the total value of the annual lumber production of the State. On the whole, the loss in timber from forest fires in the State, on a low estimate, has averaged $1,000,000 per year for the last fifteen or twenty years."

Since one species of trees is affected more than others, a kind of selection continues, which accounts for the peculiar distribution of trees in certain parts of South Jersey. Thick-bark trees and trees which produce a vigorous second growth survive the longest. Pitch pines and oaks, therefore, predominate in South Jersey, while in isolated positions, protected from fires, a great variety of trees may be found. Certain plants, although covered with a thick bark, contain substances in the form of resins, oils and waxes which are inflammable. Others contain substances which have a tendency to quench fires. The sowing of such plants along safety lines has been suggested to prevent the slow but destructive ground fires.

The white cedar, the most valuable timber tree in South Jersey, and one of the choicest soft woods of America, although growing in wet swamps, is often seriously damaged by fire. The heat, although it may not burn, is often sufficient to kill the cedar. In unusually-dry weather fires burn for many days in the bed of the swamp, destroying

in a short time what has been ages in accumulating. It is often necessary to dig deep trenches in order to check its headway. For fear of fire, cedar is cut when fit only for rails, hop-poles and laths.

The most serious damage is done to the soil. Were it not for a forest cover a large part of South Jersey would be a bed of shifting sands. Destroy that forest cover by incessant burning and such a condition can easily be produced.

In a dense forest the leaves and wood which accumulate on the surface are subjected to peculiar changes. In that material are contained the inorganic substances which the roots have absorbed from the deeper layers of the soil. Evaporation is prevented by the shade, so that this surface material retains the moisture. By the action of countless organisms this surface covering is converted into humus. Besides other inorganic substances of use to plant-growth, according to researches of Frankland and others, bacteria are continually producing nitrates, the essential of which is the element nitrogen, which is an important part of all living matter. Farmers are therefore accurate when they claim that fire "cooks" the "life" out of a sandy soil. The organic matter in the surface soil is often entirely burnt.

According to Storer, "within porous soils nitrates are doubtless formed rather freely, and, as is well known, the nitrates are easily washed out from soils, and are liable to go to waste after every rain that is long continued. They are, in fact, leached out of the soil, and the manure from which they came rapidly wastes away, It is said to be a matter of old and familiar observation in Germany, that in sandy regions in seasons that are particularly wet the soil may finally be so thorougly leached that it becomes unfruitful." When we consider the facts that nitrates are easily washed out of the soil, that they are essential to plant-growth, and that they are continually produced during the period of growth from humus by the action of nitrifying bacteria, we can appreciate the damage to light soils by fire.

When a forest is cut the young suppressed trees at once assert themselves, and the seeds on the surface quickly germinate and some kind of forest soon follows. But when a fire passes through a wood the seeds are burnt, the undergrowth killed, the soil impoverished and the land must remain unseeded until the winds or birds or man have disseminated a fresh supply of seeds over the surface.

Some seeds are more seriously damaged than others. Light, winged

kinds are, of course, quickly destroyed, while heavy, thick-coated kinds may sink into the soil and escape.

There are some interesting plants known as fire weeds, especially *Epilobium angustifolium*, which come up in abundance in burnt regions. One can often locate the site of an old coalpit by a mass of this plant. It is not likely that the seeds have endured the heat, but upon fresh seeding by the wind it is the first species able to endure the conditions produced by a fire.

According to the statements of several seamen the smoke from forest fires last summer occasioned such a fog along our coast as seriously to impede navigation.

Many animals are also destroyed. It is not uncommon to see many of the smaller animals chased by a fire. By preserving the forest, the animals dependent upon its fruits are preserved also. The birds are valuable agents of distribution. Many a beautiful wood owes its beginning to seeds accidentally dropped by birds. They also destroy many of the insects which are destructive to woods. Even the field and shore birds seek shelter in the forest. Cedar swamps are favorite nesting-places for a great variety of birds. The protection of forest and game go hand in hand, and the work of the forest warden and the game warden can be profitably combined. For the sake of wild game many beautiful forests have been preserved. These reservations, where game can breed unmolested, are valuable nuclei for the stocking of the surrounding territory with game, and for the spreading of seeds. Animals soon learn of and flock to places where they can reproduce in safety. Many birds during the fierce fires in the spring of the year, many of which originate from the preparation of land for planting, are cooked in the nest.

No improvement in the forest conditions of a country is possible as long as fires are allowed to burn without any systematic preventive measures. With no assurances whatever against incendiaries and individuals guilty of criminal carelessness, the owners of woodland are at the mercy of chance. Wood is usually cut in consequence just as soon as there is a market of any kind. Property in the towns is often endangered. Capitalists hesitate to invest in woodland under such conditions.

The total area burned over in South Jersey during the past season amounts to not less than 197,000 acres.

The most important fires since last spring have burnt approximately as follows:

No. 1 began at Wading river; probably incendiary; burnt five dwellings, one cranberry bog, injured many cedar swamps and practically destroyed the young timber on 125,000 acres. It would be impossible to calculate the damage which this fire occasioned. It produced a great deal of anxiety and several individuals barely escaped an awful death. In one instance a man's whiskers were burnt off and holes were burnt in the blanket with which he covered his horse. In another instance, while carrying his sick wife to a place of safety in the center of a field, a man's house and all other possessions were destroyed, including $100 in cash. These are only two of many such instances. The region over which it burnt in Ocean and Burlington counties will be many years in recovering.

No. 2 began at Woodmansie; probably set by lightning; burned over an area of about 25,000 acres.

No. 3 began at McKeetown; escaped from a very careless workman; destroyed one dwelling, injured several cedar swamps and covered an area of about 12,000 acres. This workman was burning brush. He left the fire to eat his dinner. A passer-by saw the danger and warned him. The warning was not heeded and a very fierce fire was the result. In such a careless way many of the fires in South Jersey originate.

No. 4 was probably set by a freight train on the road to Port Norris. It burned over an area of about 10,000 acres. The following editorial concerning this fire is copied from the "New Jersey Patriot," of Bridgeton, for April 20th, 1894:

"The freight train on the road to Port Norris set fire to the woods near Dividing Creek station on Wednesday morning. Though it would have required but little effort to extinguish the flames at first, the high wind prevailing soon fanned them into a fury which a thousand men could not have stayed.

"The wind swept it toward this city. Centre Grove was almost in the direct line of the fire, but a branch of the headwaters of Buckshutem creek checked the flames and caused them to pass both south and west of the Centre Grove neighborhood. The fire was now making rapid progress and swept on to the east and north of Lummis Mill toward the road from this city to Buckshutem. It crossed the road just this side of what is now known as the iron bridge and nearly five miles out from Bridgeton. From there it burned on both

sides of the road to what is known as the old Burlington road, leading from Fairton to Gouldtown.

"It continued across nearly to the Millville turnpike, but fortunately the wind died away later in the evening and at last the progress of the most serious fire ever in that particular part of the county was stayed.

"All through the day heavy clouds of smoke arose from the fire, and occasionally, when the fire would strike a piece of pine timber, the smoke would become much more dense. Hundreds of our citizens drove out to witness the fire, which, in the evening, presented a grand sight, and until late in the evening many walked out. In all, many thousands of acres of land were burned over, the fire having extended over an area of some ten or eleven miles in length and a probable average of two miles in width.

"Within its boundaries was much valuable sapling timber and much wood that had been cut for the market. We hear of two or three small houses that were burned and of several others in small clearings that were only saved by earnest and long-continued efforts.

"The aggregate damage was many thousands of dollars, though it is simply impossible to give an intelligent estimate of the extent of the loss.

"Since the advent of the locomotives, and through the carelessness of those burning brush in clearing lands, owners of timber lands are in constant danger of loss by fires, in addition to which the use of coal oil for fuel has caused a depreciation in the demand for wood. These causes combined caused bushland to become of but little value for growing for the general market."

Hundreds of other fires which have occurred recently throughout South Jersey are but a repetition of the same story. Incendiaries, tramps, railroads, &c., caused several smaller fires, burning over, in all, not less than 25,000 acres more.

PREVENTION.

If a fire breaks out it is seldom noticed until of considerable size. The owner of the land induces a few men to help him fight it. A fire often burns for some time, owing to the fact that fighters cannot be had. Many refuse to fight in the daytime. They wait until evening, when the fire is smouldering. Many fighters do more harm than good. These men are generally not paid. Often they are allowed to cut the dead wood. When this is refused, the landowner is considered mean and often has difficulty afterwards in finding fighters. When allowed to cut dead wood, the privilege is often abused. When

a fire once gains headway in a dry woods, propelled by a strong wind, it is difficult, if not impossible, to check it. Such work requires brave, skillful men, familiar with every foot of the region, and not men picked up here and there by chance. The rapidity of the fire depends, of course, upon the condition of the woods and the strength of the wind. Although these fires are rapid, and although the sparks may fly long distances, a stream, a spur of swamp or even a road, is sufficient to check their headway. Many fires which are very destructive burn for some time without being noticed.

The method of fighting is usually by back-firing. Fire, when properly managed in the hands of a skillful woodman, may be used to advantage in a forest. After the wind and other conditions have been noted, a party, by a short cut, rushes ahead to a road, which is always an excellent point of vantage, and burns back towards the fire. If possible, furrows are ploughed. The fires meet and the force of the main body of fire is checked or diverted. Back-firing on another man's property to save your own often causes trouble.

This much is certain about fires in South Jersey—that back-firing in the proper way is the most practical method of checking them, and that roads are excellent points of vantage. The clearing of woods for some distance on each side and the burning of safety-strips at the proper season are important steps towards the prevention of fires. Were large tracts of woodland divided into sections, and each section surrounded by fire-lanes, there would be less danger. South Jersey is such a mass of woods that when fire once gains headway it travels for miles without meeting with opposition. Fires can be much more easily controlled, however, in South Jersey than in a mountainous region. Sand, which is excellent material to fight with, is fortunately plentiful.

Proper policing by a mounted, organized, well-directed force of wardens is necessary. The territory must be divided into parts of a certain size irrespective of political divisions, a warden to a district, with the woods, roads and clearings of which he must become perfectly familiar. He is, in fact, responsible for that district. Located on a prominence with field glasses one man can control a large area in South Jersey. It must be his duty to enforce regulations and to apprehend and bring to court all offenders. It must be his duty, also, to keep a strict record of fires and other facts concerning the forests of his district.

These wardens must have the power to call on men to help them when necessary. These men must be under his control and be paid fair wages for their work. Fighting fire is such a disagreeable and laborious job that there is little wonder that competent men are difficult to find who will work for nothing. Experience in other countries shows that the presence of wardens has a strong educational influence. They can soon spot the characters who are likely to set fires, and these people, knowing that they are specially watched, would be less likely to commit such crimes. Were examples made of a few, the number of serious fires would be materially reduced.

Not only must the forest be watched to prevent the work of incendiaries and individuals guilty of carelessness, but to put out the fires which are sometimes caused by lightning.

The great success in preventing fires in Yellowstone Park, according to Captain Anderson, has resulted from constant watching by patrols along the traveled routes.

Like crime, fires cannot be wholly stopped, but they can be reduced to a minimum. The surest way to stop both crime and fires is to prevent them by constant watching.

Prof. Cook, in the Agricultural Report for 1887, came practically to the same conclusions. He said:

"The prevention of these fires is to be sought (1) by proper regulations, assumed and carried out, and (2) by judiciously-framed laws faithfully enforced.

"It is found that roads traversing the forests are frequently the means of stopping the spreading of fires. The pine forest is traversed by numerous roads, which are used as a means of access to the timber, or of passing through the forest to the various settlements. Most of these roads are at present only just wide enough to allow a wagon to pass through, not unfrequently by grazing the trunks of the trees on either side. It is invariably the practice, when a fire is to be fought, to make a stand along one of these roads, and, by firing back, to stop its progress by depriving it of food. Not unfrequently, narrow as they are, these roads alone stop the progress of the flames. It seems, then, that it would be feasible to have all these roads recorded as regularly-laid highways, with a uniform width of four rods, and to clear away all timber and brush for this width, and fire the space in the autumn, annually. It is believed that this would create a gap which the flames would rarely leap, and that they would usually be confined to a few hundred acres at most. Probably about two acres to a hundred would have to be cut off in this way to protect the rest, and in case it was seen that, because of high winds, the flames would leap

this barrier, it could be rendered effectual by a little back-firing. If this could be supplemented by a forest police of perhaps one mounted man to each 30,000 acres, making the whole annual cost not more than four cents per acre, much would be accomplished toward preventing forest fires, which now cause an average loss of sixty-seven cents per acre for the whole of the pine country. But it must also be remembered that a large amount is now annually expended in fruitlessly fighting fires, after they have become irresistible from the extent of their front."

If this excellent advice had been heeded soon after it was written, South Jersey would have been a very different country in appearance and condition from what it is to-day.

FOREST INFLUENCES.

The effect of forests on temperature and rainfall is a much-mooted question. No one has yet been able to prove that the general temperature or rainfall is affected by forests. Like a small body of water or a meadow, a forest has its local influence. A series of investigations were begun, endeavoring to ascertain the effect of forests on our local climate. It is a problem which is well-nigh insolvable. Boxes were arranged in pairs, six feet from the ground. One pair was located on the high land at an altitude of thirty feet, the other pair in the low land at an altitude of five feet. One of the first pair was located in a pine woods, the other in the open about 500 feet from it. One of the second pair was located in a small, dense cedar swamp, the other in a meadow about 300 feet away. The highest and lowest temperatures during every twenty-four hours were recorded for six months, beginning August 12th, 1894. The results of these investigations were not altogether satisfactory. They were begun in order to verify, if possible, the current belief that a cedar swamp is considerably cooler in summer and warmer in winter than other woods or open, and that a pine wood is warmer in winter than the surrounding open or deciduous woods. It has been noticed by woodmen that a cedar swamp bottom freezes only in the severest weather. Being evergreen and dense, the cedars break the wind in winter; and being located in soil full of springs, they are warmer than the upland. Coming from deeper in the earth, spring-water is apt to be cooler in summer and warmer in winter than surface-water.

TABLE SHOWING THE LOCAL VARIATIONS IN TEMPERATURE.

September, 1894.	Average minimum.	Average maximum.	October, 1891.	Average minimum.	Average maximum.	November, 1894.	Average minimum.	Average maximum.	December, 1894.	Average minimum.	Average maximum.	January, 1895.	Average minimum.	Average maximum.	February, 1895.	Average minimum.	Average maximum.
Meadow...........	59.9	79.3	Meadow...........	45.7	67.0	Meadow...........	30.4	50.9	Meadow...........	25.2	46.9	Meadow...........	20.5	41.8	Meadow..	14.1	34.8
Cedar swamp.....	60.1	75.7	Cedar swamp.....	47.8	65.2	Cedar swamp.....	31.2	50.3	Cedar swamp.....	25.9	45.0	Cedar swamp.....	20.9	39.3	Cedar swamp...	14 1	33.5
Sand field.	59.1	78.6	Sand field.	46.8	66.1	Sand field	30.5	50.8	Sand field	23.9	45.9	Sand field.	19.1	40.6	Sand field	12.9	33.8
Pine woods........	60.2	78.6	Pine woods	46.5	66.8	Pine woods.... ...	32.5	50.0	Pine woods........	25.6	45.7	Pine woods........	20.0	40.8	Pine woods	13.5	33.7

The mildness of the pines in winter is probably due to the dryness of the atmosphere and to the protection afforded by their evergreen foliage. Further investigations on this subject are, of course, necessary before conclusions are warranted.

It is more than likely that a forest cover indirectly affects the climate to considerable extent in the following way: When a sandy soil is exposed to the direct rays of the sun the moisture at once evaporates and the sand becomes unbearably hot in summer. This heats the air immediately over it, which rises in consequence and is replaced by cooler air, which in turn is heated.

The effect of forests on the precipitation of moisture is as difficult to prove as the effect on temperature. It is a common belief in South Jersey, and in common beliefs there is usually a grain of truth, that cedar swamps attract a shower. Several persons observed that more rain fell last summer in swampy regions than on the sandy upland. More than one season's observations are necessary, however, to prove that this is of general occurrence. There is one thing certain in this connection—that although forests may not actually cause the precipitation of rain, they do not prevent it, which cannot be said of a dry, sandy area.

As a windbreak the forest exerts a very beneficial influence, and the effects of masses of trees on the condition of the soil and the flow of water cannot be doubted.

The recuperative effects of forests on soils have already been referred to. In sandy soils they prevent shifting and leaching. Soils are kept in a soft, porous condition by a protective covering of vegetable matter. Compacting due to the beating of rain is prevented, and roots and rootlets not only loosen the soil but add organic matter to it by their decay.

The influence of forests on water-flow is probably not so great as is believed by some. The forest no doubt acts as a sponge, but just as soon as this sponge is saturated the excess flows off. A large amount of this moisture passes again into the atmosphere through the leaves. Erosion is prevented by a forest cover, since the countless rootlets of a tree bind the soil and retard the flow. The quantity of moisture which flows to the sea is probably the same as it ever was in South Jersey, excepting that the flow is irregular.

In South Jersey, the cultivation of the cranberry is an important industry. A stream of considerable size flows through every im-

portant bog. It is often necessary to flood these bogs on short notice. The water, therefore, must be under perfect control. The water-supply and the forest-cover (especially the cedar swamps) upon which it depends for its regularity are growing in importance to cranberry cultivators. Cedar swamps are natural reservoirs of water producing a natural irrigation. They are usually located in the region of springs. The bottom of the swamp is usually covered with bog-mosses and litter. These bog-mosses are noted for their ability to hold water. In the Southern Interior there are many streams the water of which is remarkably pure. A "branch" or "run" in percolating through these swamps divides into many streamlets and the water becomes charged with humic matter which colors it the shade of amber, but which in no way damages it for drinking purposes. The softness of this water is remarkable and the amount of soap saved in using it is considerable.

Much could be said of the sanitary influence of the pines. The protection they afford against wind and sun and other extremes must be beneficial to health. The forest soil contains many organisms, few of which, however, are in any way pathogenic. The atmosphere and soil of sandy pine regions are dry. There is a peculiar mildness to the atmosphere of South Jersey, but whether this is due to the soil, the pines, the swamp land, or a combination of these is indeed a question. No doubt one of the most beneficial influences of a forest is in preventing the formation and dissemination of dust. Aside from the beauty of trees around dwellings they do a great service, especially in cities, in this way, since septic organisms are usually carried on minute particles of matter through the air.

Were South Jersey covered with a beautiful growth of pines, such as were abundant half a century ago, hundreds of tourists would flock to it in winter. The income from that source alone would probably amount to as much as the timber it would yield would be worth. As it is, one gets a very unfavorable impression of the country in crossing in the cars to the sea, mainly because the forests have been destroyed by fires and careless cutting.

FOREST ECONOMICS.

That the Southern Interior is especially adapted to the growing of *wood crops*, owing to the favorable nature of the soil and climate, is a fact worthy of much emphasis. The nearness to a good market, if

not at present, will sometime make the growing of wood and other forest products paying industries. Transportation by small crafts is facilitated by many bays and thoroughfares along the shore, and by many navigable streams which penetrate far into the Southern Interior. A tree is long in growing and the investment is for such a time that the preservation and economical management of forests seem beyond the power of private efforts, aiming rather at the promotion of the interests of the coming generation than at the profits of the present. As the population increases, the quantity and uses of forest products, owing to the progress of discovery, increase accordingly.

It is recognized the world over by the best authorities that a forest serves at least three purposes: 1, of beauty, of special value to those regions receiving revenues from tourists and invalids; 2, of regulating the water-flow and improving the soil, of paramount importance to agricultural as well as to other regions; and 3, of yielding useful materials.

To the forester and the lumberman the first two purposes are subsidiary to the third. It must be borne in mind that the main difference between a forester and a lumberman is in the manner of using the axe and saw. One cuts carelessly; the other according to method. One is endeavoring to get every cent possible out of the forest at once; the other must content himself with a smaller and slower but perpetual income.

When a tree reaches a certain stage in its growth it is ready to cut and use, unless of special historic or other interest. It is wasteful and even detrimental to a forest to let trees mature, topple over and decay. An amount equal to the increment, and not the principal, should be cut.

On another page the planting of the white cedar, the white pine, the white oak, the swamp white oak and the chestnut is recommended. The red cedar, although common throughout South Jersey, in fact the tree of widest distribution in the United States, approaches perfection only in the mild and humid atmosphere of the Gulf States —that is, produces in the shortest time the largest amount of the best quality of wood of its kind; the white cedar, on the other hand, in the Southern Interior of New Jersey, finds a very suitable environment, producing a wood which has few, if any, equals among the soft woods of America.

The white cedar trees in the majority of the swamps have a fresh, healthy appearance. They suffer very little from the effects of insects or fungi. The damage thus caused, from an economical standpoint, is hardly worth considering. Its wood is clean, light, easily worked, durable, sweet scented and quickly seasoned. There is a mere line of pith and the bark is tough, close and fibrous. A very large proportion of the trunk is heart-wood.

In an article in the "New Jersey Forester" for March, on the wood of the white cedar, Mr. F. Roth, an authority on woods, says:

> "Perhaps no other wood in the market seasons so rapidly and perfectly as white cedar. Neither warping nor checking need be feared and almost any temperature may be employed. In lightness it is surpassed by none of the woods in Eastern markets, and in its well-grown form it equals, if not excels, even the choicest 'pumpkin' variety of the white pine, and is thus well fitted for a thousand and one uses."

It is the principal wood for general purposes in South Jersey. It is used for the parts of buildings exposed to the weather, mainly weatherboards and shingles. It is a favorite material for fences, although not so suitable for posts as red cedar and locust. It is white in color when fresh, but becomes a peculiar gray in the course of years. The wood is much used in boat and tank construction. From the slabs excelsior tow is often made, and in the Southern States, but not in New Jersey, it is much used for the manufacture of pails and hollow ware.

The white cedar tree when properly cared for is a rapid and vigorous grower. The swamps are usually entirely too dense. A large proportion of the trees are suppressed. The cedar is a surface-rooter, one tree supporting another, so that thinning at the proper time is necessary, otherwise when a few are cut others fall in every direction. Cutting the underbrush and removing the bog mosses are detrimental to the growth of the tree.

The bed of a cedar swamp is a mass of humus. The bottom is covered with ferns, bog-mosses and the like. Logs are often buried in this mass of material several feet below the surface. Many claim that more cedar is under than above ground at present in South Jersey.

The following concerning these buried logs is copied from the "Geology of New Jersey," 1868, p. 360:

"Dr. Beesley, of Dennisville, some years since communicated to the newspapers an article on the age of the cedar swamps which was copied by Mr. Lyell in his 'Travels in the United States, Second Visit,' Vol. I., p. 34, in which Dr. B. says that he counted 1,080 rings of annual growth between the center and outside of a large stump six feet in diameter, and under it lay a prostrate tree, which had fallen and been buried before the tree to which the stump belonged first sprouted. This lower trunk was five hundred years old. So that upward of fifteen centuries were thus determined, beyond the shadow of a doubt, as the age of one small portion of a bog, the depth of which is as yet unknown."

The wood of these logs is sound and light, the "mining" of which, especially in Cape May county, was for many years an important industry. They were sawed into the so-called "mud-shingles" which seem never to rot, but which wear thin in the course of years. In speaking of the mining of cedar logs, the "Geology of New Jersey," 1868, when this was quite an industry, says:

"In conducting this latter business, a great deal of skill and experience is requisite. As many of the trees were partly decayed and worthless when they fell, it becomes important to judge of the value of the timber before much labor is wasted upon it. With an iron rod the shingler sounds the swamp until he finds what he judges to be a good log; he tries its length and size with this rod; with a sharp-cutting spade he digs through the roots and down to it; he next manages to get a chip from it, by the *smell* of which he can tell whether it was a *windfall* or a *breakdown;* that is, whether it was blown down or broken off. The former are the best, as they were probably sound when they fell. If he judges it worth working, he cuts out the matted roots and earth from over it, and saws it off at the ends. This latter operation is easily performed, as the mud is very soft, and without any grit. By means of levers he then loosens it, when it at once rises and floats in the water, which is always very near the level of the swamp. The log is then cut into shingle lengths, and split into shingles. The logs are sometimes, though rarely, worked for thirty feet.

"It is very interesting to see one of these logs raised. It comes up with as much buoyancy as a freshly-fallen cedar; not being water-logged at all. The bark on the under side looks fresh, as if it had lain but a few days; and what is remarkable, the under side of the log is always the lightest; the workmen observe that when the log floats in the water it always turns over, the side which was down coming uppermost."*

*Op. cited pp. 357-358.

A cedar swamp is so dense that the light only feebly penetrates, so that the weakest trees are overwhelmed and grow but little, or die in consequence. The general opinion is that cedar grows best when not mixed with other trees. The tapering tops of the trees project beyond the body of the swamp and the foliage causes such a shade that there is little underwood. The white pine and cedar, however, seem to grow well together. Cedar is such a lover of sunshine that it cannot thrive when much shaded by other trees, and the shade which it causes is such that few trees can endure it. Very tall, quick-growing trees which throw little shade, such as pines, and which have a strong, deep root system, grow well with cedar.

By removing the lower limbs, which are usually dead, clean timber can be produced. If the dead limbs are not removed the knots thus formed in the board, being loose, drop out.

When the surroundings are unfavorable cedar grows slowly and lichens (especially *Usnea barbata, var. florida*) accumulate on its bark in consequence. Its wood becomes "brazzly" or brittle. When growing alone or on the edge of a swamp the tendency of trees to grow in a spiral manner is well illustrated by the cedar. To a board from such a tree there is neither a right nor a wrong side. It splinters in every direction.

The white pine is not common in South Jersey, although it deserves considerable attention. On the lowlands it grows with surprising rapidity and soon overtops the other trees. It thrives in medium lands, and, unlike the white cedar, will grow on sandy uplands. The seeds of the white pine may be bought of nurserymen for about $2 a pound.

The chestnut has been strongly recommended for planting in South Jersey in places which are free from fires. Several letters have been received, testifying to the fact that it grows well on light soils. Although easily affected by fires, it yields large returns in a few years, producing a useful wood and a salable fruit. The second growth is vigorous and the tree lives and fruits for many years. The celebrated chestnut trees on the slopes of Mt. Ætna must be counted among the oldest trees on earth, being as old, according to some authorities, as the Christian era. Many varieties of the chestnut are under cultivation, differing considerably in the size of the tree and in the size and quality of the nut. Before planting for its fruit, those who are not familiar with its cultivation should consult a horticulturist. The

chestnut is certainly one of the most useful and beautiful of trees, and since it thrives in South Jersey, deserves to be planted, especially along streets, although it is much clubbed and disfigured by boys while in fruit.

The walnut (*Juglans nigra*) is a valuable tree for its wood and nuts. Although associated with rich woods, it grows rapidly in the light, loamy soils of South Jersey. Several very handsome specimens may be seen in Atlantic and Cape May counties.

The Madeira nut, or English walnut (*Juglans regia*), is a native of Persia, but will grow in light, moist soil in this climate. The value of its nuts is well known, and there is every reason for believing that it can very profitably be cultivated in South Jersey.

The hazelnut is rare in South Jersey, although it is a profitable underwood. It was planted around Calico and Old Martha, in Burlington county, in the woods where it is still found growing and fruiting.

The pecan (*Carya olivæformis*) will grow in South Jersey, but its cultivation so far north has not proved successful.

Much could be said of the minor forest products of South Jersey, which, although gathered in small quantities by many individuals, are by no means of minor importance. Employment is thus furnished to many backwoodsmen, who help themselves to whatever they can find of such a nature in the woods.

Scattered in pine woods are "fat-pine knots." These were gathered during the civil war to supply the demand for tar. A kiln was built in the ground, into which these knots were put. By firing the top the tar oozed out and trickled down into vessels placed ready to receive it. Such an industry would not pay to-day; it was profitable only during the war, when the Southern supply was interrupted.

These knots are valuable, however, for kindling, and when slivered and bundled will sell in large cities.

In Europe the cultivation of the basket willow is an important industry. There is no better plant for holding soil in places exposed to washing along fresh-water streams. It can be easily propagated and grows rapidly.

The wood of the willow is more valuable than is usually supposed. It holds a nail tenaciously, and although soft, is firm. The wood of the white willow in England is used for many purposes, especially in

the manufacture of cricket bats. The wood of the black willow has been used to considerable extent by ship-builders in South Jersey.

Mr. H. Sabsovich, superintendent of the Baron de Hirsch colony at Woodbine, has been experimenting with basket willows. He reports that he has grown them very successfully on land practically unfit for other purposes. The willow has been grown along the Delaware for charcoal.

Market-baskets are made from the wood of the sweet gum (*Liquidambar styraciflua*). The log is sawed into pieces of the proper length and each is cut into thin circular sheets. When the sticks get too small in circumference to be conveniently cut, they are sold for rollers. The bottoms of the baskets are usually of pine.

Many claim that the wood of the persimmon is excellent for shuttles and spindles. This is no doubt so, since the persimmon belongs to a famous family in respect to its wood.

The wood of the holly is valuable for the manufacture of fancy articles.

The wood of the sour gum is used for special purposes. It is irregularly grained and proverbially tough. It is used for wagon-hubs, hatters' blocks, malls and the like. It is often turned into pillars for porches.

Laurel (*Kalmia latifolia*), calico bush or spoonwood, is valued for rustic work. It is used extensively for that purpose in the building of fences, summer-houses, benches and the like. The large butts of the laurel bush, vulgarly known as "nigger-heads," are much used in the manufacture of pipes.

Tannin is a material common to many plants. It is yielded by several species of sumac, mainly the common upland variety which grows in very dry, sandy fields. The rankest and healthiest specimens noticed by the writer were on gravelly soil in Washington township of Burlington county. At one time the leaves were gathered in large quantities and powdered by mills in South Jersey. Why this industry stopped is not known to the writer, but sumac is still common and tannin much used for a variety of purposes. In Sicily a species of sumac has been cultivated for many years for that purpose.

Red cedar oil was once extracted in South Jersey. Sassafras yields a fragrant oil, which is used to a limited extent, and the aromatic bark of its root is gathered and sold.

The hoop-pole industry was important at one time in South Jersey. Much of the second growth of oak was utilized in that way, but owing to the substitution of bags for barrels and iron for wooden hoops there is little or no demand at present.

In the bottom of cedar swamps there is a moss called sphagnum, which may be considered a forest product. This forms a spongy mass over the surface sometimes more than a couple of feet in depth. This material is noted for its ability to hold water and also to undergo an extreme amount of drying and still recover. It is used by nurserymen for packing purposes. In Ocean county it is baled in hay-presses and shipped in large quantities. This custom ought to be prohibited, at least to a certain extent, since it robs the swamps of a very valuable material. Cedar swamps are natural reservoirs of water, and in this respect the sphagnum plays an important part in helping to retain it. In very dry weather, owing to the density of the foliage above and the mass of sphagnum below, swamps remain damp. Moss-gatherers usually help themselves to this material wherever they can find it.

The American mistletoe (*Phoradendron flavescens*) was at one time very common in South Jersey. It is a parasite on the sour-gum. According to some authorities, the red maple is also its host. It begins on the branches, moves towards the trunk, gnarls, and finally kills the tree which supports it. It is becoming scarce, but has been much gathered, especially at Christmas time, and with holly and other evergreens is sold in cities.

The flowers of the magnolia (*Magnolia glauca*), which scent the woods in June, are also a source of revenue.

In many places in South Jersey there are large quantities of young birch, also plenty of scrub oak. These are cut in large quantities for canes and umbrella handles. Holly is used for the same purpose.

The swamp huckleberry is a fruit deserving more attention than it has ever received. It is a good swamp underwood. It can easily be cultivated and improved. Huckleberry-pickers break off the bushes, since they have noticed that the young wood which follows bears a larger quantity of better-flavored berries.

The fruit of the persimmon is often sold in our markets. It is sweet and wholesome, but soft and difficult to transport.

Wild grapes, gumberries, beach plums, wild cherries, juniper berries and the like are all more or less used for wines, pies, jellies, &c.

There are other products yielded by the small plants which grow in the woods. Acorns are abundant and are much gathered for swine.

A firm at Vineland has been buying forest leaves for the manufacture of linoleum. The success of this venture is not a certainty. It is mainly an experimental plant.

Many of our common trees and shrubs yield medicines of more or less value, such as witch hazel, wild cherry, white-oak bark, spicewood, &c.

Wood has been sold in South Jersey for the manufacture of pyroligneous acid and alcohol. Pyroligneous acid is crude acetic acid, the essential of vinegar derived from wood by distillation. The time is no doubt coming when the chemist will utilize what is now destroyed as waste.

The staghorn sumac (*Rhus typhina*) is sometimes called the vinegar tree, from the use of its acid fruit in vinegar, while its near relatives, *R. venenata* and *R. toxicodendron*, both common in South Jersey, are to some persons exceedingly poisonous. *Rhus toxicodendron* is used to some extent in medicine. *Rhus typhina*, which grows to be a small tree, has been planted to considerable extent in yards in South Jersey, but is very rare in the woods.

In conclusion, efforts in the following lines are recommended: The education of the coming generation in the principles of forestry; the prevention of fires and wood-thieving by proper policing; the taxation of woodland in proportion to the interest which it yields; the reforestation of large areas of waste land by the State; caring for forests on areas which supply large cities with water; encouraging settlers to leave wood-lots on their farms; and the planting of suitable trees along streets and roads, in parks, botanic gardens and around our houses.

MINERAL STATISTICS.

IRON ORE.

The statistics of production of iron ore in New Jersey in 1894 are given in the following report of John Birkinbine, of Philadelphia, special agent of the United States Geological Survey, Division of Mining Statistics:

"DEPARTMENT OF THE INTERIOR.
"UNITED STATES GEOLOGICAL SURVEY,
"DIVISION OF MINING STATISTICS AND TECHNOLOGY.
"PHILADELPHIA, April 23d, 1895.

"*Prof. J. C. Smock, State Geologist. Trenton, N. J.*:

"DEAR SIR—As agreed, I have compiled the figures of the production and valuation, &c., of the iron ores of New Jersey for the calendar year ending December 31st, 1894, and would make the following report:

"The total amount of iron ore (all of which was of the magnetic variety) produced during the year was 277,483 gross tons. The total valuation of the iron ore produced during the year was $568,056. This is equivalent to $2.05 per gross ton. The stocks of ore on hand December 31st, 1893, were 62,038 gross tons. The stocks of ore on hand December 31st, 1894, were 63,317 gross tons. This would show that the shipments during the year 1894, amounted to 276,204 gross tons.

"It may be interesting to you to have a review of the production of iron ore in the six years for which we have data in this office together with the stocks reported on hand at the close of each year, and the valuation of the iron ore production of New Jersey for the four years in which it was collected. These are set forth in the following table:

"PRODUCTION, VALUATION AND STOCKS OF IRON ORE IN NEW JERSEY, 1889–1894.

Years.	Rank as a producer.	Production. Gross tons.	Total valuation.	Valuation per ton.	Stock on hand December 31st.
1889......	9th	415,510	$1,341,543	$3.23	94,890
1890......	8th	495,808	Not reported.	....	Not reported.
1891......	9th	525,612	Not reported.	....	64,856
1892......	8th	465,455	$1,388,875	2.98	72,390
1893......	9th	356,150	909,458	2.55	62,038
1894......	8th	277,483	568,056	2.05	63,517

"It may also be of interest to state that the States which produced more iron ore in 1894 than New Jersey were Michigan, Minnesota, Alabama, Virginia, Pennsylvania, Wisconsin and Tennessee, in the order named.

"Yours respectfully,

"JNO. BIRKINBINE.

"The 'rank as a producer' shows the position held by New Jersey among the States which supplied iron ore, based on the quantity mined in each of the years named.

"J. B."

The total shipments of iron ore from New Jersey stations, and from mines in the State, reported by the several railway companies carrying the ore in 1894, with the output of the mines at Oxford Furnace, which was not included in the railway reports, amounted to 284,787 tons.

The statistics of last year's report are here reprinted:

IRON ORE.

1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000 tons	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.
1864	226,000 tons	Annual Report State Geologist.
1867	275,067 tons	" " "
1870	362,636 tons	U. S. census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons*	
1877	315,000 tons*	
1878	409,674 tons	" " "
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "
1885	330,000 tons	" " "
1886	500,501 tons	" " "

* From statistics collected later.

1887.........	547,889 tons	Annual Report State Geologist.
1888.........	447,738 tons	" " "
1889.........	482,169 tons	" " "
1890.........	552,996 tons	" " "
1891.........	551,358 tons	" " "
1892.........	465,455 tons	" " "
1893.........	356,150 tons	" " "

ZINC ORE.

The zinc ore mined in the State in 1894, reported by the companies working the mines at Stirling Hill and at Franklin Furnace, in Sussex county, amounted to 59,382 tons.

The statistics for preceding years are reprinted:

1868.........	25,000 tons*............	Annual Report State Geologist.
1871.........	22,000 tons	" " "
1873.........	17,500 tons	" " "
1874.........	13,500 tons	" " "
1878.........	14,467 tons	" " "
1879.........	21,937 tons	" " "
1880.........	28,311 tons	" " "
1881.........	49,178 tons	" " "
1882.........	40,138 tons	" " "
1883.........	56,085 tons	" " "
1884.........	40,094 tons	" " "
1885.........	38,526 tons	" " "
1886.........	43,877 tons	" " "
1887.........	50,220 tons	" " "
1888.........	46,377 tons	" " "
1889.........	56,154 tons	" " "
1890.........	49,618 tons	" " "
1891.........	76,032 tons	" " "
1892.........	77,298 tons	" " "
1893.........	55,852 tons	" " "

* Estimated for 1868 and 1871. Statistics for 1873 to 1890, inclusive, are from reports of the railway companies carrying the ores to market. The reports for 1890, 1891, 1892 and 1893 were from the companies working the mines.

PUBLICATIONS OF THE SURVEY.

DISTRIBUTION OF PUBLICATIONS.

The demand for the publications of the Survey has increased during the past year.

There is a continued call for the topographical maps. The sales during the last year amounted to $400.

It is the wish of the Board of Managers to complete, as far as possible, incomplete sets of the publications of the Survey, chiefly files of the Annual Reports, in public libraries, and librarians are urged to correspond with the State Geologist concerning this matter.

By the act of 1864 the Board of Managers of the Survey is a board of publication with power to issue and distribute the publications as they may be authorized. The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed largely by members of the two houses. Extra copies are supplied to the Board of Managers of the Geological Survey and the State Geologist, who distribute them to libraries and public institutions, and as far as possible, to any who may be interested in the subjects of which they treat. Several of the reports, notably those of 1868, 1873, 1876, 1879, 1880 and 1881, are out of print and can no longer be supplied by the office. The first volume of the Final Report, published in 1888, was mostly distributed during the following year, and the demand for it has been far beyond the supply. The first and second parts of the second volume have also been distributed to the citizens and schools of the State, and to others interested in the particular subjects of which they treat. The third volume is now being distributed from the office of the State Geologist. The appended list makes brief mention of all the publications of the present Survey since its inception in 1864, with a statement of editions that are now out of print. The publications of the Survey are, as usual, distributed without further expense than that of transportation, except in a single instance of the maps,

where a fee to cover the cost of paper and printing is charged as stated.

CATALOGUE OF PUBLICATIONS.

GEOLOGY OF NEW JERSEY, Newark, 1868. 8vo., xxiv.+899 pp. Out of print.

PORTFOLIO OF MAPS accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron ore and limestone districts; colored. Scale, 2 miles to an inch.

2. Triassic formation, including the red sandstone and trap rocks of Central New Jersey; colored. Scale, 2 miles to an inch.

3. Cretaceous formation, including the greensand-marl beds; colored. Scale, 2 miles to an inch.

4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.

5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.

6. Map of the Ringwood iron mines; printed in two colors. Scale, 8 inches to 1 mile.

7. Map of Oxford Furnace iron-ore veins. colored. Scale, 8 inches to 1 mile.

8. Map of the zinc mines, Sussex county, colored. Scale, 8 inches to 1 mile.

A few copies are undistributed.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for fire-brick, pottery, &c. Trenton, 1878, 8vo., viii.+381 pp., with map. Out of print.

A PRELIMINARY CATALOGUE of the Flora of New Jersey, compiled by N. L. Britton, Ph.D. New Brunswick, 1881, 8vo., xi.+233 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi.+439 pp. Very scarce.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part I. Mineralogy. Botany. Trenton, 1889, 8vo., x.+642 pp.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton, 1890, 8vo., x.+824 pp.

REPORT ON WATER-SUPPLY, by Cornelius Clarkson Vermeule. Vol. III. of the Final Report of the State Geologist. Trenton, 1894, 8vo., xvi.+352 and 96 pp.

BRACHIOPODA AND LAMELLIBRANCHIATA of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield, Trenton, 1886, quarto, pp. 338, plates XXXV. and Map. (Paléontology, Vol. I.)

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield, Trenton, 1892, quarto, pp. 402, plates L. (Paleontology, Vol. II.)

ATLAS OF NEW JERSEY. The complete work is made up of twenty sheets, each twenty-seven by thirty-seven inches, including margin, intended to fold once across, making the leaves of the Atlas 18½ by 27 inches. The location and number of each map are given below. Those from 1 to 17 are on the scale of one mile to an inch.

No. 1. Kittatinny Valley and Mountain, from Hope to the State line.
No. 2. Southwestern Highlands with the southwest part of Kittatinny valley.
No. 3. Central Highlands, including all of Morris county west of Boonton, and Sussex south and east of Newton.
No. 4. Northeastern Highlands, including the country lying between Deckertown, Dover, Paterson and Suffern.
No. 5. Vicinity of Flemington, from Somerville and Princeton westward to the Delaware.
No. 6. The Valley of the Passaic, with the country eastward to Newark and southward to the Raritan river.
No. 7. The Counties of Bergen, Hudson and Essex, with parts of Passaic and Union.
No. 8. Vicinity of Trenton, from New Brunswick to Bordentown.
No. 9. Monmouth Shore, with the interior from Metuchen to Lakewood.
No. 10. Vicinity of Salem, from Swedesboro and Bridgeton westward to the Delaware.
No. 11. Vicinity of Camden, to Burlington, Winslow, Elmer and Swedesboro.

No. 12. *Vicinity of Mount Holly*, from Bordentown southward to Winslow and Woodmansie.
No. 13. *Vicinity of Barnegat Bay*, with the greater part of Ocean county.
No. 14. *Vicinity of Bridgeton*, from Allowaystown and Vineland southward to the Delaware bay shore.
No. 15. *Southern Interior*, the country lying between Atco, Millville and Egg Harbor City.
No. 16. *Egg Harbor and Vicinity*, including the Atlantic shore from Barnegat to Great Egg Harbor.
No. 17. *Cape May*, with the country westward to Maurice river.
No. 18. *New Jersey State Map.* Scale, 5 miles to an inch. Geographic.
No. 19. *New Jersey Relief Map.* Scale, 5 miles to the inch. Hypsometric.
No. 20. *New Jersey Geological Map.* Scale, 5 miles to the inch.

The maps comprising THE ATLAS OF NEW JERSEY are sold at the cost of paper and printing, for the uniform price of 25 cents per sheet, either singly or in lots. Payment, invariably in advance, should be made to Mr. Irving S. Upson, assistant in charge of office, New Brunswick, N. J., who will give all orders prompt attention.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to His Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo., 24 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to His Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1865. Trenton, 1866, 8vo., 12 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, on the Geological Survey for the year 1866. Trenton, 1867, 8vo., 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year 1867. Trenton, 1868, 8vo., 28 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1869. Trenton, 1870, 8vo., 57 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1872. Trenton, 1872, 8vo , 44 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1873. Trenton, 1874, 8vo., 128 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1874. Trenton, 1874, 8vo., 115 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1875. Trenton, 1875, 8vo., 41 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1876. Trenton, 1876, 8vo., 56 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1877. Trenton, 1877, 8vo., 55 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1878. Trenton, 1878, 8vo., 131 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1879. Trenton, 1879, 8vo., 199 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1880. Trenton, 1880, 8vo., 220 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1881. Trenton, 1881, 8vo , 87+107+xiv. pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1882. Camden, 1882, 8vo., 191 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8vo., 254 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo., 45 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo., 87 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo., 112 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1890. Trenton, 1891, 8vo., 305 pp. with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1891. Trenton, 1892, 8vo., xii.+270 pp , with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1892. Trenton, 1893, 8vo., x.+368 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x.+452 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo.

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ERRATA.

Page 164.—To follow the genera in order, read first both columns above "Hydrosera (Terpsinœ) Novæ-Cæsareæ," and then in order the two columns below.

Page 165.—Similarly read first the two columns above "Surirella Woolmaniana," and then the two columns below.

Page 165.—Read at the bottom of this page as among the wells *along the coast,*

"At Wildwood, N. J., between the depths of 370 feet and 793 feet."

This line has been wrongly placed, in the re-arrangement of the type, among the *inland* wells, at the top of the next page.

Page 169.—Fifth line from bottom, for "Raphidodiscus," read "Rhaphidodiscus."

Page 177.—Ninth line from top, for "Dollinger," read "Dallinger."

Page 181.—Twentieth line from top, for "Linnen," read "Linnæus."

Page 187.—Third, fourth, fifth and sixth lines from the bottom first column, for "Actinoptyclus," read "Actinoptychus." Eleventh line from the bottom second column, for "*Mancula,*" read "*Navicula.*"

Page 192.—Eighteenth line from the bottom, read "the" before "Miocene."

Page 204.—NOTE.—On this page wells at Gibbsboro and Harrisonville are noted as having been placed upon the Marlton and Medford section (Plate X.) In final preparation of the plate it was thought best, for clearness of illustration, to omit these wells. By an oversight the text was not corrected to correspond. The well at Quinton, noted in the last paragraph on this page, was omitted, since to place it in its proper position, some miles to the southeast, would have unduly lengthened the plate. The relation of this well to the wells at Woodstown and to the one at Joseph Evans', near Marlton, can be seen by reference to the preceding Plate IX., which, being drawn upon a smaller horizontal scale, includes a wider belt.

pocket contains 1 item

GEOLOGICAL SURVEY OF NEW JERSEY.

Annual Report of the State Geologist for 1894.

GEOLOGICAL MAP

OF THE

VALLEY OF THE PASSAIC.

BY

ROLLIN D. SALISBURY.